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R. T. LEIPER, M.D., D.Sc., F.R.S.,

Professor of Helminthology in the University of London.

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Observations on the Morphology and life history of *Ascaris columnaris* Leidy, a nematode parasite of the skunk.

By T. Goodey, D.Sc., and
T. W. M. Cameron, M.A., B.Sc., M.R.C.V.S.

Introduction.

The breeding and raising of small mammals, such as skunk, minx and fox, for their fur, is a comparatively young industry in Britain, and one of the most serious hindrances to the successful husbandry of these animals is the occurrence, at any rate, in the skunk, of certain helminth parasites. We have been investigating the worms sent to us from a skunk farm, where the stock is very extensively infected, and where serious injury to the animals and great deterioration of the coat is attributed to these parasites.

The most important worm encountered is a nematode of the Ascarid type, which we have determined as *Ascaris columnaris* Leidy, 1856.

The skunks in which the worms occur are the North American species, *Mephitis mephitica*. We are indebted to the owner for the following brief particulars of the symptoms shown by infected animals :—

The back is arched and the abdomen raised, as though to avoid contact with the ground. The hind-quarters consequently have a " tucked-up " appearance. The coat becomes " staring," with loss of quality and change of colour, the black becoming brown and the white creamy and then yellow. There is also loss of appetite, with consequent emaciation and, finally, death.

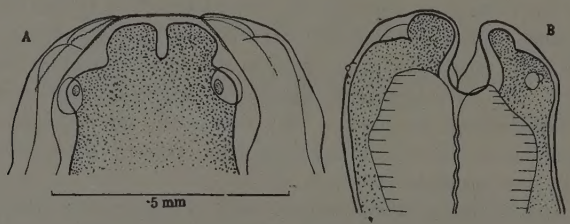
The work has been under the general direction of Prof. R. T. Leiper, to whom we are indebted for suggestions and criticisms.

Historical.

In 1851, Leidy (2) described from the skunk (*Mephitis americana*), from Pennsylvania, an Ascarid worm, which he believed to be *Ascaris alienata* Rud.

His description is as follows :—" Body nearly uniformly cylindrical, white ; mouth prominent, with three lips prominent and very distinct. No membranous or other appendages. *Female.*—Body cylindrical to within four lines of the mouth, when it gradually becomes narrowed ; posteriorly straight abruptly narrowed into a very small obtuse tail, $\frac{1}{5}$ line from the anus. Whole length 4" 3"' ; breadth $1\frac{1}{5}$"'. *Male.*—Cylindrical, attenuated towards the extremities ; posterior extremity incurved without appendages ; tail short and curved ; length 2 inches ; breadth $\frac{3}{4}$"'."

Leidy remarks that this worm corresponds in every particular, except in size, being twice as large, with the *Ascaris alienata* obtained from *Nasua rufa* by Rudolphi.



Ascaris columnaris.
Fig. A. Lips seen from dorsal view.
Fig. B. Seen from lateral view, showing the pulp and dentigerous ridges.

In 1856 (3), however, he altered the name to *Ascaris columnaris* Leidy, quoting *Ascaris alienata* Rud as a synonym. He gives no reason for the change, and his diagnosis is unaltered—though slightly abbreviated. Leidy also changed the name of the host to *Mephitis chinga*.

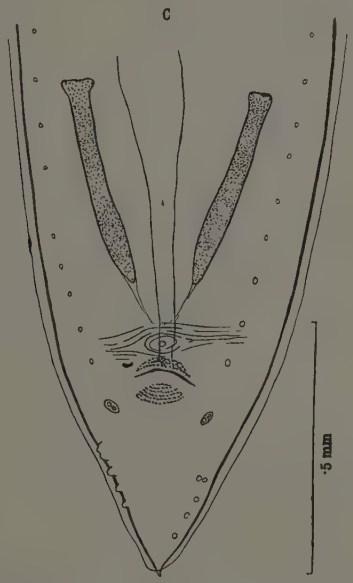
ASCARIS COLUMNARIS Leidy, 1856.
(Syn. *A. alienta* Rud. of Leidy, 1851.)

Hosts. *Mephitis chinga* (*americana*), *Mephitis mephitica.*
Distribution. N. America, Britain (imported).

Length, male to 9 cm., female to 22.5 cm. ; breadth, male to 2 mm., female to 3 mm. Body white and tapering towards both ends. The cuticle is transversely striated, the striation being about .02 mm. apart The head is small, about .4 mm. in diameter. There are three simple lips without interlabia. The lips are somewhat hexagonal in outline,

The dorsal lip bears two papillæ, the ventral lips one each. The papillæ are circular and single. The pulp of each lip is anteriorly divided into two lobes, which are situated medially (Fig. A and B), dentigerous ridges are well developed.

The œsophagus is about $\frac{1}{80}$ of the body length. Except for a slight swelling anteriorly (Fig. B) it is of almost uniform diameter for its entire length. It is entirely muscular, has no ventriculus, and has no attach-

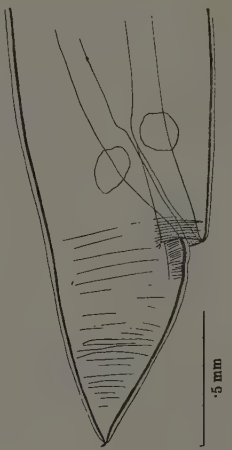


Ascaris columnaris. Fig. C. Tail of male, showing papillæ, cloacal pads and spicules.

ments to the body wall. There are no œsophageal or intestinal diverticula.

The Male.—The male tail terminates in a small "spike" about 20mm. long. This spike is of parenchymatous origin, and projects through the cuticle, which is slightly swollen in this region. The cloaca is about 0.4 mm. from the posterior end. The preanal papillæ, of which there are about 36 pairs, are situated in two slightly divergent rows, and are somewhat irregularly spaced. There is a single median papilla just anterior to the cloaca (Fig. C). There is a pair of *double* anal papillæ lateral to

or just posterior of the cloaca. There are normally five pairs of irregularly distributed post-anal papillæ. The first two on each side are frequently fused, giving the appearance of a double papillæ. The number is also somewhat irregular, there being occasionally three or four only on one or both sides. The most frequent variation is four on one side and five on the other. The spicules are equal, about 0.4 mm. long. Their greatest thickness is about .06 mm. anteriorly. They taper gradually and terminate bluntly. Slightly raised roughened pads are present, anterior and posterior to the cloaca (Fig. C).



Ascaris columnaris. Fig. D. Posterior end of female.

The Female.—The posterior region of the female terminates in a spike, similar to that in the male. The anus is situated about 0.8 mm. from the tail, and is a transverse slit protected by a cuticular pocket (Fig. D). There is a thick, short rectum with conspicuous rectal glands. There are two slight lateral thickenings of the body wall, about $\frac{2}{3}$ of the distance between anus and tail.

The vulva is a transverse slit, which is situated about the junction of the anterior and second quarter of the body. The internal female organs

are as in *A. megalocephala*. The uteri are fused for a distance of 1.25 mm., and are continued as a single thick walled vagina, 3 mm. long.

The ova are .088 to .090 mm. long by .066 to .068 mm. broad. The shell is finely mammillated and has a thickness of about .0055 mm. Within this there is another membrane, having a loose plicated appearance. It is this membrane, as in the eggs of *A. megalocephala* and *A. lumbricoides*, which is so resistant to acids, alkalis, etc., and possesses selectively permeable properties.

Life History.

Egg-cultures.—In order to work on the development of the worm, eggs were obtained by dissection of mature female worms and the removal of the anterior inch or two of the uteri as described in earlier work on *Ascaris megalocephala* (1). The eggs were forced out from the minced uteri by gentle pressure and the liquid used for culturing them was formalin of about 2 per cent. strength. It was found that the shell membranes possessed properties essentially similar to those of eggs of *A. megalocephala* and *A. lumbricoides*, since the egg contents developed quite well in weak formalin.

Eggs were also obtained from skunk droppings by mixing with water, filtering off the coarse matter and centrifuging the filtrate. These eggs developed equally well in weak formalin. The cultures were put-up in Petri dishes, and incubated at about 33° C.; this being the optimum temperature for development in the case of eggs of *A. megalocephala* and *A. lumbricoides*. The cultures were frequently oxygenated by agitating the liquid and the occasional addition of oxygenated tap-water. A large percentage of eggs became embryonated in the course of a fortnight, and it was noticeable that each embryo filled out the space of the egg very completely.

Eggs in fæces left at laboratory temperature became embryonated in about one month, so that in all probability they would take about the same length of time in the open.

The Embryo.—Eggs from the cultures were placed on slides and covered with coverslips. By pressure on the coverslip a number of eggs were ruptured, and the embryos forced out (Fig. E). It was then seen that each embryo was provided with a very delicate sheath, a feature which had not been discernible in examination through the egg shell, as can be done

in the case of *A. megalocephala*. The embryo is comparatively stout in relation to its length, proportionately much stouter than the embryo of *A. megalocephala*. In length it is about .34 to .345 mm., and has a breadth of about .02 mm., as compared to the larva of *A. megalocephala*, which has a length of about .27 mm., and a breadth of .012 to .015 mm. At its anterior end the larva has a very pronounced boss set on the bluntly rounded body. The latter is about the same width throughout most of its length, only tapering a little towards the tail, which ends in a kind of stump, on which, in many cases, a small knob is visible, though this is not present in all cases. Lateral lines are present. The excretory pore is situated on the ventral surface, about .055 mm. from the anterior end, and the anus is about .035 mm. from the end of the tail. The alimentary canal is divided into two well defined regions, œsophagus and intestine. The former extends backwards for about .11 mm. from the anterior end, and the intestine stretches from this point to within about .02 mm. of the anus, with which it is connected by a narrow rectum. The intestinal region is very granular in appearance. There are indications of a developing nerve ring around the œsophagus, just in front of the excretory pore. The genital primordium is found on the ventral side of the intestine, about half-way down its length.

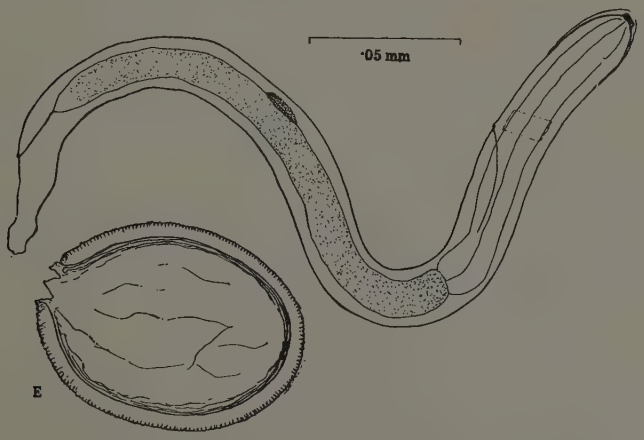
Infection Experiments.—Two mice, which had been fasting for twelve hours, were fed with biscuit crumbs, which had been moistened with water containing washed embryonated eggs in suspension. One mouse was fed with eggs taken from a culture made from uterine material, and the other with eggs collected from skunk droppings. The number of eggs administered in this way was not computed, but it was probably several thousands. An exactly similar feed was given to each animal on the following day, and on the two succeeding days they received ordinary food.

On the fourth day after their first feed of infective food, both mice were showing signs of illness, and were very sluggish in their movements.

Both were chloroformed, and the body cavities were opened up, when it was seen that the liver and lungs in each case were in an unhealthy condition. The liver showed the usual creamy spots which have frequently been observed in cases of larval *Ascarid* infection, and the lungs were heavily congested and had numerous bright-red hæmorrhagic patches on the surface.

Small portions of both organs were removed and pressed between sheets of glass in normal saline, and examined under the microscope, and in each case active larvæ were found, exactly similar in appearance to those obtained by the rupture of embryonated eggs. The larvæ were more numerous in the preparations from the lungs than from the liver.

The rest of the bodies were then fixed entire in 10 per cent. formalin and, in due course, portions of the lungs were removed, and after the usual treatment were embedded in paraffin and sectionised. On examining these sections fragments of larvæ were found.



Ascaris columnaris. Fig. E. Larva hatched from egg-shell by pressure.

Discussion.

It is clear from these results that the larvæ of *A. columnaris* follow the same mode of development and pursue the same migratory course in the body of the host as do those of *A. lumbricoides, A. megalocephala, A. vitulorum, Toxascaris sp.*, and *Belascris sp., Ophidascris filaria* and *Polydelphis attennata* from the python.

Since also they can cause serious pulmonary trouble in an experimental animal, it seems reasonable to infer that in the skunk itself they would be similarly pathogenic, if the embryonated eggs were taken in sufficiently large quantities.

We have no evidence to offer, however, of observed pneumonic symptoms in skunks on the farm, and one may judge from this that in all probability the infections with eggs are at no time massive. There must, however, be constant reinfection of the stock by means of embryonated eggs, since adult and immature worms are constantly present in the intestine and the owner experiences great difficulty in getting rid of the parasites by treatment with the vermifuge employed up to the present time.

The problem of the eradication of the parasites now becomes reduced to one of proper sanitation and hygiene of the skunk farm, together with the provision and administration of an efficient vermifuge for the expulsion of the worms.

We are hopeful of providing satisfactory solutions to both sides of the problem. Already a commencement has been made to check reinfection by the daily collection of all droppings, and their disposal in a site away from the animals.

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Journal of Helminthology, vol. 1, pp. 9-20.

Observations on the genus *Paragonimus* Braun with a re-description of *P. compactus* (Cobbold, 1859) 1899.

By G. M. Vevers, M.R.C.S., L.R.C.P., F.Z.S.
Beit Memorial Research Fellow.

Historical.

The earliest record of a mammalian lung fluke was made by Diesing in 1850, who described *Distomum rude* from the lungs of *Lutra brasiliense*, from Brazil. This species was transferred to the genus *Paragonimus* by Stiles and Hassall in 1900.

In 1859 Cobbold described a form which he named *Distoma compactum*, from the lungs of *Viverra mungos*, India. This species was placed in the genus *Paragonimus* by Braun in 1899.

Eighteen years later Westerman, the Director of the Zoological Gardens at Amsterdam, sent some trematodes from the lungs of a tiger to Kerbert, who, in 1878, described them as new to science, and named the species *Distomum westermanii*.

In 1881 Kerbert received more specimens from a tiger which died in the Hamburg Zoological Gardens. These proved to be identical with those from the previous case, and he published a complete morphological study of the species. It is interesting to note that in the first paper (1878) he spoke of the fluke as *D. westermanii*, whereas in the second paper (1881) he calls it *D. westermani* throughout. The latter spelling is correct, but the first has priority and, therefore, should stand.

The next record is by Manson, in 1880, who found trematode eggs in the sputum of a Chinaman. He communicated this fact to Cobbold, and also sent him a fluke from the lung of a Portugese given to him by Dr. Ringer. This fluke Cobbold named *Distomum ringeri*. This is the first record of such a parasite occurring in man, the next being that of Baelz, who in 1883 published a description of a fluke from the lung of man in Japan, which he named *Distomum pulmonale*. This species, and the *D. pulmonis* of the Japanese writers of this time were considered

synonymous with *D. ringeri*, and therefore both names were eventually dropped.

Leuckart, in 1889, compared *D. westermanii* Kerbert with specimens sent to him by Baelz, and considered them to be the same species.

This takes us to the time when the old group, Distomum, was broken up into smaller genera, and in 1899 Braun formed the Genus *Paragonimus*, with *P. westermanii* as the type of the genus.

The first record of a lung fluke in N. America was published by Ward, in 1894, from a cat in Michigan, and this he assigned to the species *P. westermanii*, although he noticed several differences between his specimens and the descriptions of *P. westermanii* as given by Kerbert and Leuckart.

This case was at first considered not to be evidence of the endemic occurrence of the parasite in N. America, as there was a possibility of the cat being imported. However, this doubt was overcome by Stiles and Hassall in 1900, who recorded many cases of pigs in Cincinnati, Ohio. These parasites were considered by Stiles and Hassall to be a variety of *P. westermanii*.

Kellicott, in 1894, also recorded it from the dog in U.S.A., and this was considered by Ward to be identical with those from the cat, mentioned above, and, therefore, was diagnosed as *P. westermanii*. In 1908 Ward pointed out that the form from cats, dogs and pigs in N. America was a different species, and to it he gave the name *Paragonimus kellicotti*. In the same paper Ward also suggested that the Japanese form was a separate species, and later, in 1915, in a joint paper with Hirsch, he stated that the Japanese form must bear the name of *Paragonimus ringeri* (Cobbold, 1880).

These earlier writers based the specific characters on the shape and size of the body and internal organs, points which subsequently proved valueless, owing to their extreme variability in individual specimens of the same species.

It was during an endeavour to find some constant character upon which the species of this genus might be easily differentiated, that Ward and Hirsch (1915) discovered that the cuticular spines present in all the known species differed in size, shape and arrangement.

On this character alone they were able to differentiate the three species, *P. westermanii, P. ringeri and P. kellicotti.*

Material and Methods of Diagnosis.

During the last three years lung flukes have been found in five mammalian hosts, which died in the Zoological Gardens of London: India mongoose (*Mungos mungo*), India (3 cases); Leopard cat (*Felis bengalensis*), India; Tiger (*Felis tigris*), Malay States.

Cuticular Spines.

I have been able to use the cuticular spines in the specific diagnosis of all the specimens collected, thus confirming Ward and Hirsch's view that this method is the most reliable way of dividing up the genus.

In addition to the three species (*P. kellicotti*, *P. ringeri* and *P. westermanii*) whose spines were examined and described by these authors,

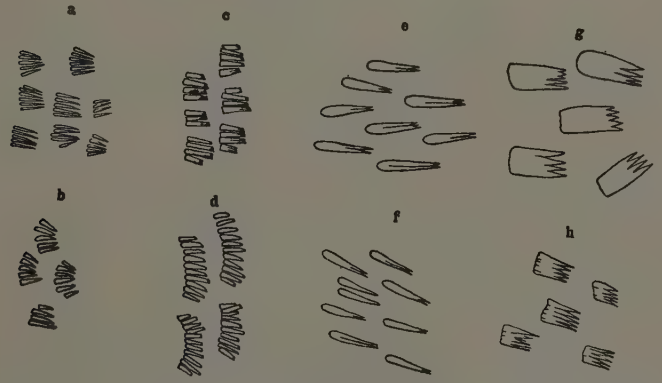

Fig. 1. Spines taken from between oral and ventral suckers: (a) *P. compactus*, (c) *P. ringeri*, (e) *P. westermanii*, (g) *P. kellicotti*.
Spines taken from between testes (b) *P. compactus*, (d) *P. ringeri*, (f) *P. westermanii*, (h) *P. kellicotti*.
(*All spines drawn to same scale.*)

I have, from my material, collected on three occasions at the Zoological Gardens, studied and drawn the spines of *P. compactus* (Cobbold), collected from the type host *Mungos mungo*. In this species also there is a marked difference in the shape and arrangement of the spines, which distinguish it from the other species, and it would thus seem that we have a definite, constant character upon which we may divide up this difficult genus, in which it has proved impossible to arrive at an exact specific

determination upon the shape, size and position of the internal organs, which vary so greatly in individual specimens.

In using this method of diagnosis care must be taken to always examine the spines or groups of spines from the same area, as the shape and arrangement varies in different parts of the body, though always in a constant manner. Total mounts were prepared in all cases, and the most convenient point to examine was found to be the area midway between the oral and the ventral suckers; another point which may be used is the clear area between the testes.

The species of the genus may be divided into two groups upon the disposition of the spines, one group being *P. ringeri* and *P. compactus*, in which the spines are arranged in small clusters, and the other group being composed of those in which the spines are scattered singly on the cuticle, viz., *P. westermanii* and *P. kellicotti*. The spines of the two last, although they occur singly, are really composed, in the case of *P. westermanii*, of two spines fused together, and in *P. kellicotti*, of four or more likewise fused together to form a chisel shaped spine with a serrated edge.

Eggs.

The eggs of the species of Paragonimus differ considerably from one another, and vary in the individual species.

The average sizes of the eggs are :—

P. westermanii	.085 mm. × .055 mm.
P. ringeri	.09 mm. × .055 mm.
P. kellicotti	.084 mm. × .05 mm.
P. compactus	.075 mm. × .048 mm.

It will be seen that the egg of *P. compactus* is smaller than the egg of any of the other three species.

There is another point of difference between the eggs of *P. compactus* and those of *P. kellicotti* and *P. ringeri*, which seems to be constant; in both the latter the shell is markedly thickened at the opposite pole to the operculum, whereas in *P. compactus* the shell is almost the same thickness throughout, except at the opposite end to the operculum, where there is a very small knob. A similar knob occurs in the egg of *P. westermanii*, and by this one can distinguish it from the egg of *P. kellicotti*, with which it agrees in size.

The larger size of the egg of *P. westermanii* is sufficient to differentiate it from that of *P. compactus*, with which it agrees in outline.

Through the kindness of Prof. R. T. Leiper I have been able to examine the type specimens of *P. ringeri* and *P. compactus*, and find that the average size of the egg of *P. ringeri* is .09 mm. × .055 mm. This is the largest of all the eggs under consideration.

The differences in size and outline are shown in Fig. 2, a.b.c.d., all

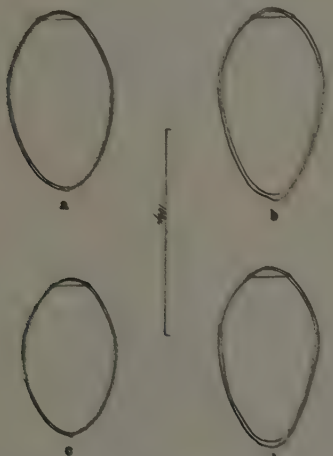

Fig. 2. Eggs: (a) *P. westermanii*, (b) *P. ringeri*, (c) *P. compactus*, (d) *P. baltzetti*.

drawn to scale by means of the camera lucida.

Reference to a paper by Ward, published in 1903, shows a considerable variation in the sizes of the eggs from human cases of Paragonimiasis, described by various authors. These variations may be due to errors of observation or differences in technique, but it is highly probable that more than one, if not all four species, may occur, and have occurred, in man, and this would naturally account for the differences in the size of the eggs recorded.

Geographical Distribution.

Paragonimus ringeri would seem to be confined to China and Japan, whereas in India and the Malay States man is liable to be infected with *P. compactus*, *P. westermanii* and *P. kellicotti*. As far as we know *P. kellicotti* is the only species which is endemic in North and South America, and therefore is the species which would attack man, if man proved to be a suitable host.

Systematic Description.

Troglotremidæ Odhner, 1914.

P. compactus (Cobbold, 1859) Braun, 1899.

(Syn. *Distomun compactum* Cobbold, 1859.)

Host. *Mungos mungo*.
Habitat. Lungs.
Locality. India.

It would appear from the literature that there has been no record of the occurrence of this parasite, since it was originally described by Cobbold 63 years ago.

According to present day standards of classification, the original description is somewhat inadequate. In view of this, and also that it is more than probable that this species is also a parasite of man, I consider that a somewhat fuller description of this fluke, based on the material collected in the Zoological Gardens, will not be out of place.

This species is smaller than any of the other known species of Paragonimus—in the fresh unmounted state it measures from 4 mm. to 5 mm. in length, 2.5 mm. to 3 mm. in breadth, and 1.3 mm. to 2 mm. in thickness. When fresh it is of a reddish-brown colour, and is capable of assuming many shapes, so that no reliance can be placed on the position of the ventral sucker as a specific characteristic, as this can easily vary a millimetre in either direction.

The cuticle, especially that portion anterior to the ventral sucker, is closely studded with groups of from 4-7 small lanceolate spines, measuring .01 mm.-.025 mm. in length. (*See* Text, Fig. 1, a and b.) As in the other species of the genus, these spines vary in size and shape in different parts of the body, but are always arranged in groups or clusters, and are

constant in any number of individuals. The oral sucker is terminal in a properly extended specimen, and measures from .4 mm.-6.mm. in diameter. A well marked muscular pharynx is present, measuring .3 mm.-.45 mm. in diameter. The bifurcation of the gut takes place immediately behind the pharynx, and the branches which are broad and tortuous run back to within .5 mm. from the posterior end of the body.

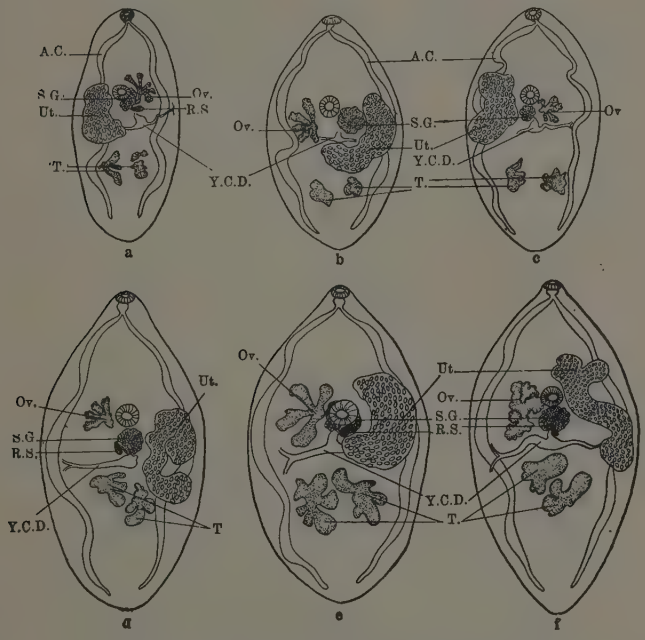

Fig. 3. Paragonimus compactus from lungs of *Mungos mungo*, India, showing variability in shape, size and arrangement of internal organs. (*The yolk glands have been omitted. All are drawn to same scale.*)

The ventral sucker is well defined and circular, measuring from .6 mm.-.8 mm. in outside diameter.

The excretory system consists of a large pyriform vesicle, which divides

the body longitudinally in two parts, and opens posteriorly in the terminal excretory pore.

Genital Organs.—The size, shape, and position of the male and female genitalia vary considerably in different individuals—this may be seen best by reference to Figures 3, a-f, which are all drawn to the same scale. The ovary consists of five club-shaped lobes, each lobe being again subdivided into smaller lobulations, especially at the free, broad end. As this fluke, like all the other members of the genus, is amphitypical, the ovary may occur on either side of the body opposite to the sac-like uterus, which usually occupies the middle third of the body on the one side.

The receptaculum seminis, which is not well-marked in the other members of this genus, is quite prominent in *P. compactus*, staining a deep blue with Ehrlich's hæmatoxylin in total preparations. It is a small pear shaped organ, situated at the junction of the two yolk collecting ducts and measuring .35 mm. × .015 mm. when fully distended.

The shell gland which lies directly behind it is a large diffuse oval organ, .7 mm. long by .5 mm. in greatest breadth.

The two yolk collecting ducts which join to form a common yolk duct are in most specimens very large and conspicuous. The yolk glands themselves, which have the wide distribution common to the genus, are dendritic in form, and are subject to a considerable amount of variation in individual specimens. The common genital pore is situated immediately behind the ventral sucker in the mid line of the body.

Laurer's canal is present, but can only be seen in sections of the parasite ; it opens half-way down on the dorsal surface of the body in the mid line.

The two testes which lie on either side of the body at the junction of the posterior and middle thirds are separated from one another by the excretory vesicle. Their shape and size varies enormously, and it is difficult to describe them, save as being lobed organs of size, varying from .5 mm. to 1.5 mm. in diameter, the lobes being 3-5 in number.

The eggs are operculated and measure from .072 mm. × .045 mm. to .078 mm. × .049 mm., the shell is of the same thickness throughout, except at the opposite pole to the operculum, where there is a very small thickening in the form of a knob. When freshly passed the eggs contain a single ovum surrounded by yolk cells.

PARAGONIMUS WESTERMANII (Kerbert, 1878) Braun, 1899.

Four specimens were found in the lungs of *Felis bengalensis*, India. Ward and Hirsch (1915) give a figure of the cuticular spines from the

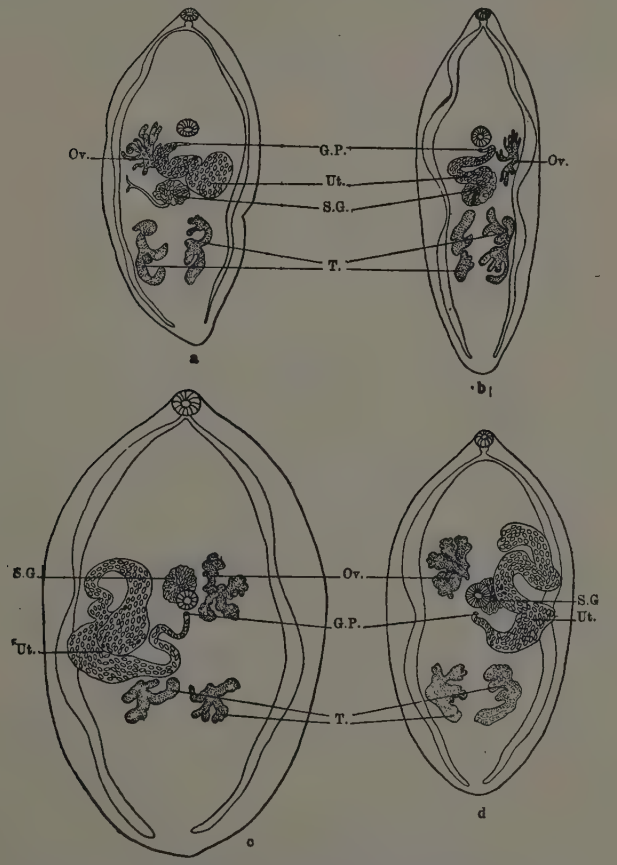

Fig. 4. *a, b.* P. westermanii from lungs of *Felis bengalensis*, India.
c. d. P. kellicotti from the lungs of *Felis tigris*, Malay States.
(Both pairs show amphitypism and variability in size and shape. Yolk glands have been omitted.)

type specimen of *P. westermanii*. They are of a single lanceolate type,

with here and there a suggestion of fusion by pairs. A comparison of their figure with the spines from my material from *F. bengalensis* show that they are identical.

From Fig. 4, a and b, it will be seen that the ovary is markedly lobed, and that the lobes differ from those in the other species of Paragonimus; this should not be taken into account as a specific character, as there is so much variation in the shape of the ovary in other members of the genus. (*See* Fig. 3, a to f.)

Paragonimus kellicotti Ward, 1908.

This species was found in large numbers in the lungs of *Felis tigris* from the Malay States.

The cuticular spines correspond to the drawings given by Ward and Hirsch of those from *P. kellicotti*.

Through the kindness of Colonel Clayton Lane, who allowed me to cut serial sections through a specimen of *P. kellicotti*, given to him by Prof. H. B. Ward, I was able to compare the internal structure of this fluke with a similar series of sections of the one from the Malay Tiger. I could find no point upon which to base a specific difference after making allowance for the extremes of variability which are met with in the genus.

As far as I can ascertain, this is the first record of *P. kellicotti* from Asia, which is curious, as this fluke originally came from Asia, the aboriginal home of the large Carnivores. Probably specimens have been found, but were diagnosed as *P. westermanii*, no attention being paid to the cuticular spines.

It is possible also that *Distomum rude* Diesing, is identical with *P. kellicotti*, as the latter is the only known species of the genus endemic in America.

The probability is increased by the fact that certain other parasites of Carnivores are common to Asia and South America, for example *Platynosoma fastosum* Kossack, in wild cats from Malacca and British Guiana, and *Ancylostoma pluridentatum* Alessandrini, in the Malay Tiger and *Felis mitis* from Brazil. As these continents have been separated since early Pleistocene times, it would seem that the evolution of the parasite is slow compared with the evolution of the host.

Conclusions.

(1) At present, four distinct species of Paragonimus are known: *P. westermanii*, *P. ringeri*, *P. kellicotti* and *P. compactus*.

(2) The internal organs of each species vary so much in individual specimens that no reliance can be placed upon them, as far as specific diagnosis is concerned.

(3) The most reliable way of distinguishing these species is by means of the cuticular spines.

(4) There are certain specific differences in the shape and morphology of the egg shell.

(5) Probably more than one of these species occurs in man.

(6) *P. kellicotti* occurs in Asia as well as America.

(7) In all probability *Distomum rude* Diesing, and *P. kellicotti* are identical. This cannot be proved without either the re-examination of Diesing's original material, or from further specimens from the Type host, *Lutra brasiliensis* from Brazil.

(8) The rate of evolution of the parasite is slow in comparison with the rate of evolution of the host.

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Journal of Helminthology, Vol. 1, pp. 21-28.

On the Free-Living Larval Stages of the Nematode *Bunostomum trigonocephalum* (Rud.) a Parasite of Sheep.

By A. J. Hesse, B.Sc., Ph.D.

The only account of the larval stages of *Bunostomum trigonocephalum* (Rud.) which I have been able to find is a brief note by Baillet (1866), in which he states that the larvæ of *Uncinaria cernua* Crep. = *B. trigonocephalum* (Rud.), develop in water and hatch within four or six days. The newly hatched larvæ are "rhabditiform," .35 to .4 mm. long and .23 to .3 mm. broad, and the tail is very thin and filiform.

I have been able to obtain abundant adult examples of *B. trigonocephalum* from the abattoir at Gorgie, Edinburgh, through the kindness of Mr. Jones, O.B.E., M.R.C.V.S., and with the help of Mr. T. W. M. Cameron, M.A., B.Sc., M.R.C.V.S. The work has been done in the Department of Zoology of the University of Edinburgh, and I am indebted to Professor J. H. Ashworth for advice during its progress.

Freshly collected adult females of *Bunostomum trigonocephalum* from the small intestine of the sheep were placed one or two at a time on a slide in water, and the terminal part of the uterus opened with fine needles so as to liberate the eggs. These were placed in a culture fluid made by adding to water fresh fæces, from the sheep's large intestine. The fæces had first been carefully examined and all eggs removed. The cultures were placed in Petri-dishes and kept (*a*) in an incubator at a temperature of 22-23° C., (*b*) at laboratory temperature. The eggs kept at room temperature in water and fæces take from 48 to 72 hours to hatch, but the larval stages correspond with those obtained from eggs kept at 22° C. In a cooler room hatching required five days, while at 22° C. it takes place in twenty-four hours.

The egg of *Bunostomum trigonocephalum* is ellipsoidal or globular, and is usually slightly flattened on one side. The shell is thin and without any ornamentation, and at one pole is slightly thickened. The eggs vary in length from .08 to .093 mm. (average .085 mm.) and in breadth

from .047 to .065 mm. (average .05 mm.). The eggs in the terminal part of the uterus, ready to be passed, have undergone three or four cleavages, *i.e.*, are in the 8-celled or 16-celled stage. Eggs removed from the uterus in the 2-celled condition continue to develop in the culture. The cells are granular, but as cleavage proceeds become more transparent. The remaining granules are chiefly around the nucleus and the cytoplasm towards the periphery of the cell is vacuolated. Between the ovum and the egg-shell is a space, but in some cases this is seen only at one pole.

The First Larval Stage.

After 24 hours at a uniform temperature of 22° to 23° C. the larvæ have already hatched or are in the process of hatching. The larva breaks through the shell at a point near, but lateral to, one pole. The body is truncated at the anterior end and is of a more or less uniform diameter as far as the anus. The maximum diameter, however, is at the level of the œsophageal bulb, or the region between the bulb and the genital primordia.

Posterior to the anus the body gradually tapers down to an acutely pointed tail, the extreme point being often hairlike and recurved.

The length of the larva varies usually from .36 to .5 mm., but a few .6 mm. long have been seen, and the breadth is .02 to .035 mm. The cuticle is thin and faintly striated transversely, especially in the posterior region. The oral aperture is surrounded by six processes, two ventral, two dorsal, and one on each side of the mouth. The lateral lines are very faint; the dorsal and ventral lines were not observed. The entire larva is translucent and the refractile granules in the body can be easily seen.

Leading from the mouth to the œsophagus is a short buccal capsule, .008 to .02 mm. long and .0025 mm. broad, the walls of which appear as two clear parallel lines. The œsophagus is generally flexed and about .1 to .13 mm. long; it has the typical "rhabditiform" structure, being divided into three regions, an anterior thickened region about .005 to .01 mm. thick, a slightly thinner middle region and a posterior bulb .006 to .0125 mm. broad. The bulb has a characteristic Y-shaped valve and a posterior thickening, the primordium of the intestinal valves.

The nuclei of the œsophageal cells are visible, especially after the larva

has been under the coverslip for some time. A transverse striation is also visible in all three divisions of the œsophagus.

The chyle intestine consists of eight dorsal and eight ventral cells, bounding a lumen, the first part of which is dilated and the remainder runs in a " zig-zag " course. The cells of the intestine in the first stage larva are difficult to make out, because the body cavity, as well as the cells, contain numerous scattered refractile granules. The rectum is short, surrounded by a few cells. The anus opens on the ventral side, .07 to .14 mm. from the tip of the tail.

The elements of the nervous system are recognisable. A fibrous ring, together with some cells, encircle the œsophagus about .067 to .09 mm. from the anterior end. Immediately posterior to it is on each side of the œsophagus a mass of nerve cells which constitutes the lateral nerve

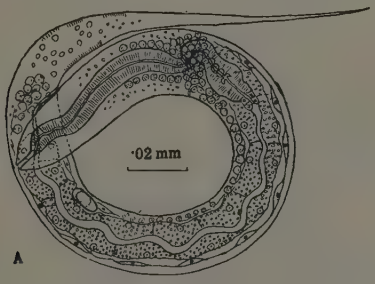

Fig. A. *Bunostomum trigonocephalum.* First larval stage.

ganglion. The anterior dorsal cord, the anterior ventral cord, the ventral cord, and the lateral nerve cords are represented each as a few cells placed end to end. The ventral nerve cord is the most developed, and can be seen as a string of deeply staining cells extending backwards opposite the ventral line. No nerve cells were observed in the dorsal line. Long spindle shaped muscle-cells (Fig. A) were, however, traced as a linear series towards the posterior end ; similar muscle cells are also present in the ventral line, but the string of rounded nerve-cells obscures them.

The excretory system consists of a fine tubule opening on the ventral side, about .07 mm. from the anterior end and surrounded by a few cells. The genital primordia are represented by two closely apposed, clear

oval, refractile bodies, .01 mm. long and .004 mm. broad, on the ventral side of the chyle intestine .17 to .2 mm. from the anterior end of the worm. The part of the tail posterior to the anus contains a few indistinct cells and granules. These cells probably represent the " pulvillus postanalis," from which arise the bursal structures and spicules, and also certain rectal glands of the adult. The terminal part of the body or tail proper is noncellular and cuticular.

The newly hatched larva presses its anterior end against the fæcal mass, and during feeding the lumen of the anterior part of the œsophagus expands and contracts from time to time, while the Y-shaped valve of the bulb, which probably prevents regurgitation, also dilates and contracts. The movements of the larva are limited to the lashing movements employed in progression, and to coiling and uncoiling.

The Second Larval Stage.

After 24 hours, at a temperature of 22° to 23° C., the first stage larva becomes quiescent, the cuticle becomes loosened and the new cuticle of the second larval stage is formed. Actual moulting was not observed, but many moulted cuticles were found in the culture. As soon as the old cuticle is cast the second stage larva becomes active again. The shape of the larva is little changed, except that the tail is in many cases not so acutely pointed. The cuticle is thicker and more distinctly striated, as can be well seen in those examples still ensheathed in the old cuticle. The processes surrounding the mouth are more prominent, as also are the lateral lines, the double contour of which is now clear. The double contour of the lateral lines is sufficient to prove that a moult has taken place. The larvæ are .45 to .6 mm. long, .02 to .03 mm. broad, the size depending on that of the first stage larva from which they are derived. The larva has become slightly longer, but not broader.

The œsophagus in some specimens, especially those in preparation for the second moult, shows a slight difference, the anterior and middle part having become uniform in breadth. The " rhabditiform " character of the œsophagus is generally carried on into the initial stage of the " filariform " larva, and only gradually disappears, so that a normal " filariform " stage of 24 hours has a " claviform " œsophagus. The lumen of the intestine in the second stage is less " zig-zag " in outline, and the intestinal cells are more demarcated owing to the concentration

of reserve material in them. The anus is about .08 to .12 mm. from the tip of the tail on the ventral side. The cells surrounding the rectum are more distinct, and extend posterior to the anus. There are some large cells surrounding the part of the rectum where it joins the intestine (Fig. B.).

The nervous system has become more compact. The ventral cord can now be definitely traced to the rectal region. The excretory pore is situated opposite the bend in the œsophagus on the ventral side, about .1 to .13 mm. from the anterior end. From the pore a definite and clear canal extends dorsally and posteriorly. The genital primordia are more clearly distinguishable bodies, and occupy a concavity in one of the ventral intestinal cells, about .17 to .3 mm. from the anterior end. The second stage larvæ, kept at 22° C., feed on fæces for about 24 hours and then most of them show two, three, or a series of wrinkles in the cuticle

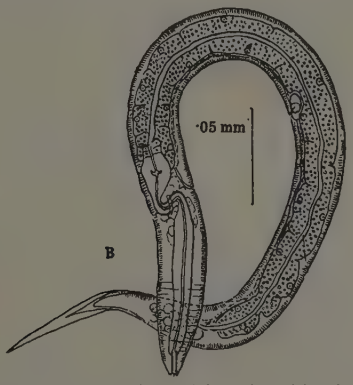

Fig. B. *Bunostomum trigonocephalum.* Second larval stage.

in the anterior region due to the contraction of the larva, and a new cuticle becomes visible under the old one. The larva again becomes quiescent and 24 hours after the first moult the second moult takes place.

The Third Larval or "Filariform" Stage.

The old cuticle is not cast during the second moult, but remains closely adherent to the larva. Some contraction of the larva must have taken place for the sheath projects a little distance in front of the anterior end of the larva. The larva, with its sheath, is .45 to .7 mm. long and .2 to

.25 mm. broad. The sheath still shows the vestiges of the six anterior processes at its anterior end, and the transverse striation noted on the second stage. The posterior extremity is usually blunt, but it may be tapering and pointed (Fig. C).

The buccal capsule in most specimens has become short and funnel shaped. The œsophagus is in the form of a long anterior part, and a slightly thicker posterior part. The posterior part has lost its Y-shaped valve and is truncated posteriorly where it joins the intestine. This kind of œsophagus, which is termed " claviform," is characteristic of many ensheathed larval nematodes. The intestinal cells are much more clearly demarcated, and each is in the form of a large spindle-shaped cell with a clear nucleus situated at its broadest part and away from the lumen. The dorsal nuclei usually alternate with the ventral. Under a low power the granules in the cytoplasm of the cells give them a yellowish-green appearance, and the entire larva appears greenish. The lumen of the intestine is much compressed, and appears as a single wavy line. The anus of the larva is closed and often does not lie opposite the anus in the sheath.

The nervous system is compact and in stained specimens the posterior region of the œsophagus is covered with a mass of deeply staining cells. The ventral cord becomes connected with a mass of deeply staining cells in the anal region, which probably represents a ganglion. The genital primordia are situated about .3 to .4 mm. from the anterior end on the ventral side of the body. Each is a deeply staining lens-shaped mass .01 to .015 mm. long, consisting of many cells.

The " filariform " stage is very active, swimming for a time in a serpentine fashion and then tending to sink. This stage does not feed, and in order to develop further it must gain entrance into its definitive host, the sheep. The larvæ are sensitive to changes of temperature. They become very active at a temperature of 22° C., but if the temperature is raised further they become quiescent. If the point of a hot needle be applied under a slide, beneath a drop of water containing larvæ, they show active movements and swim *away* from the centre of heat.

The resistance of the " filariform " larva is striking. Larvæ can swim in formalin, a mixture of ether and alcohol, and concentrated solutions of pancreatin, for some time. Like the larvæ of *Hæmonchus contortus*,

Graphidium strigosum and *Trichostrongylus retortæformis*, they can withstand desiccation for an indefinite time. Some ensheathed stages were placed on a slide in a drop of water and allowed to dry on 24th June. On 3rd July they revived on the addition of a drop of water, and revived again on 11th August. The majority of them coil up on desiccation, but others are either straight or only slightly coiled. The sheath becomes wrinkled, and the enclosed larvæ shrink so that very little of their structure can be made out. The revival is due to the penetration of water through the sheath, enabling the larvæ again to take up water, expand and become motile.

The free-swimming " filariform " stage can survive in stagnant water for a long time. Specimens were kept alive for over a month in a closed dish containing water mixed with fæces. The only visible change that takes place is the disappearance of reserve granules from the intestinal cells. The larva thus derives its nutrition from the reserve material stored up during its first and second stages. A comparison with the

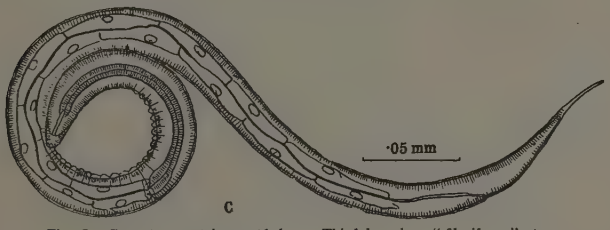

Fig. C. *Bunostomum trigonocephalum*. Third larval or " filariform " stage.

habits of other ensheathed larvæ leads one to the conclusion that these probably do not penetrate the skin, but are ingested through the mouth.

Under natural conditions the larvæ are probably ingested by the sheep in the moisture on grass or after they have become dried on blades of grass. As the larvæ begin to dry up they aggregate into small groups. They do not migrate up the sides of the dish, as do those of *Ancylostoma duodenale*. Several blades of grass were placed upright in a loosely corked tube with a small quantity of water containing numerous active larvæ. The blades of grass were frequently examined, and although they were covered with drops of water, no larvæ were ever observed on them. Even when nearly all the water had condensed on the blades

and the sides of the tube, no larvæ were found on either ; they were all aggregated together at the bottom of the tube around the stems of the grass. This suggests that the larvæ of *Bunostomum trigonocephalum* do not migrate up blades of grass like the ensheathed forms of *Hæmonchus contortus*. Their position on the grass is a matter of chance, and they simply remain in some hollow or loop in a blade of grass as the water evaporates.

Remark on Starved Forms.

The eggs placed in pure water without any fæcal material, and subjected to 22° C., hatched after 24 hours, and the larvæ passed through all the stages and became ensheathed on the fourth day. The only differences are that these larvæ, especially the second stage and " filariform " stage, possess very few reserve granules, and are much smaller. The tail is generally more acutely pointed in the starved than in the fed examples.

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Journal of Helminthology, vol. 1., pp. 29-33.

On a Trematode from the Gall Bladder of Naja bungarus with an emendment of the Genus *Xenopharynx* Nicoll, 1912.

By M. Khalil, M.D., Ph.D.

During August, 1922, acting as an Honorary Parasitologist to the Zoological Society of London, I examined an Indian Cobra, the "Hamadryad" *Naja bungarus*, which died in the Society's gardens. A single trematode was found in the Gall bladder. It was living and active. A careful search for other examples of this trematode in the snake proved negative.

The trematode was examined alive and notes were taken of its anatomy, and then it was fixed and stained. The accompanying camera lucida drawing is of the parasite after being flattened and stained.

Morphology.

Measurements of the mounted specimen give about 5.12 mm. for the maximum length, and about 2 mm. for the maximum breadth.

The greatest width of the worm is near the caudal extremity. The body is flattened dorso-ventrally and tapers more towards the oral pore than towards the caudal pole. The caudal extremity is broad, rounded from side to side, and presents the aperture of the excretory system. The cephalic extremity is conical and presents at its vortex the oral aperture.

The general surface of the worm is unprovided with spines or papillæ.

The genital pore lies on the top of a slightly protruding papilla in the median sagittal plane close to the cephalic extremity, at the level of the bifurcation of the intestinal cæca. The pore is 0.6 mm. from the cephalic end.

The acetabulum is comparatively small, being 0.25 mm. in diameter. It lies in the median sagittal plane on the ventral surface, 1.1 mm. from the cephalic pole.

The oral sucker is 0.3 mm. in diameter. The oral aperture is 0.15 mm. in diameter. The oral aperture leads into a well-formed muscular

pharynx. The pharynx measures 0.14 × 0.16 mm. It is thus broader than it is long.

The œsophagus is short and thick. It passes directly caudad. It is 0.25 mm. in length and 0.24 mm. in maximum diameter.

The intestinal cæca join the œsophagus at nearly a right angle, and bending graceful pass directly caudad to the caudal pole. During the last portion of their course they bend slightly from side to side and approach each other. The blind ends of the intestinal cæca are 0.35 mm. from the caudal pole.

The sexual organs, with the exception of the vitelline glands, are disposed in the intercæcal area.

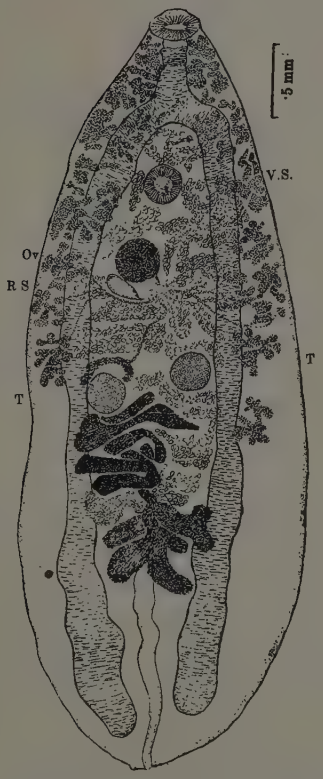
Male Organs.—There are two smoothly rounded testes placed very slightly diagonal. Their fields are separate, but the zones overlap to a great extent. The very thin vas efferens could not be traced during all its course. Close to the genital opening the wavy course of the vas deferens could be seen running cephalad to its termination. No vesicula seminalis could be seen. Each testis is 0.27 mm. in diameter, lying close to the corresponding intestinal cæcum. The two testes lie practically midway between the cephalic and the caudal poles, one on either side of the middle line, the left testis being slightly cephalad of the right testis.

Female Organs.—The ovary and shell gland are in the cephalic portion of the worm between the cephalic testis and the acetabulum. The ovary is larger than the testis. It is 0.3 mm. in diameter. It is globular in shape with a smooth outline. It lies slightly to the right of the median sagittal plane 0.3 mm. caudad of the acetabulum. The oviduct springs from the dorsal aspect of the ovary and proceeds slightly to the left, to enter the shell gland. Laurer's canal could not be seen in this one specimen. The shell gland lies practically in the median sagittal plane to the left and slightly caudad of the ovary. It is about 0.15 mm. in diameter.

The oviduct unites in the substance of the shell gland with the vitelline duct. The latter duct, resulting from the union of the right and left vitelline ducts penetrates the caudal aspect of the shell gland. The union of these ducts results in the formation of the ootype.

The receptaculum seminis is a pear shaped sac lying caudad of the

ovary to the right of the median sagittal plane. Its pointed end lies nearer to the middle line, and from it begins a duct which apparently



Xenopharynx solus Nicoll, 1912.
Ov=ovary, RS=receptaculum seminis, T=testes, V.S.=ventral sucker.

traverses the shell gland. The length of the receptaculum seminis is 0.27 mm., and its maximum diameter is 0.12 mm.

The uterus begins from the ootype in the shell gland, and runs directly

caudad passing between the two testes. Caudad of the testes the uterus forms transversely lying coils between the two intestinal cæca, reaching within 1.25 mm. of the caudal pole. The coils then run cephalad, passing again between the two testes and to the left of the ovary to the genital pore. In this part of its course the coils of the uterus overlap the intestinal cæca.

The eggs are oval in shape, with an operculum at one end. They measure .038 mm. in length and .021 mm. in breadth.

The yolk glands occupy mainly the extracæcal area in the cephalic half of the worm. They consist of well formed and closely packed follicles. Cephalad the yolk glands reach the level of the oral sucker and closely surround the pharynx and œsophagus. Caudad they terminate at the level of the testes, with the exception of one follicle, which lies caudad of the testes. From either side proceeds a vitelline duct slightly caudad of the ovary. The two ducts meet close to the shell gland.

The excretory vesicle has a characteristic Y shape with a long median stem running from a little cephalad of the testes to the caudal pole. The two limbs of the vesicle reach cephalad as far as the level of the vitelline ducts.

Discussion.

In 1912 Nicoll described a trematode parasite from the gall bladder of *Naja tripudians*, India. He named it *Xenopharynx solus* g. et sp. nov. Its main characters, according to him, are (1) The peculiar pharynx. (2) Two diagonal testes pre-ovarian and post acetabular. (3) Yolk glands, extending as far forwards as the oral sucker, and backwards to the region of the ovary. (4) Excretory vesicle large and Y shaped.

Judging from the general contour, shape of body, size and distribution of yolk glands, excretory system and acetabulum, the parasite shows a great resemblance, if not actual identity, with the parasite described in this paper. Added to this is the close relationship of the two hosts, which are Indian cobras of the same genus, and the habitat being in each case the gall bladder and also the peculiar fact that a single specimen was found in each case.

According to Nicoll the testes in his specimen were pre-ovarian, just the opposite of what I found in my specimen. The vitelline ducts are figured by Nicoll joining each other closely caudad of the anterior testis.

This peculiar arrangement suggested that Nicoll might have mistaken the ovary for the anterior testis. I was not able to examine Nicoll's type specimen, but I was fortunate enough to get him to examine my specimen. He agreed that the two specimens are possibly identical. He attributed his mistake to the macerated condition of his type specimen.

It is thus necessary to redefine the genus XENOPHARYNX in the light of the description recorded in this paper. The genus is transferred from the DICROCŒLIIDÆ to the TELORCHINÆ, Looss, 1899. The genus may be defined thus :—

Body-elongate and flattened, cuticle without spines. Acetabular aperture midventral pre-equatorial. Genital pore pre-acetabular. Oral sucker larger than acetabulum. Pharynx present, cæca simple, long.

Male organs : Testes diagonal, intercæcal, surface without in foldings. Post-ovarian.

Female organs : Ovary intercæcal, in uterine zone, post acetabular, pretesticular. Uterus with descending and ascending limb, intercæcal. Vitellaria extracæcal, limited to the anterior half of the body.

Excretory system : Excretory bladder, roomy, long, Y shaped.

Type species : *Xenopharynx solus* Nicoll, 1912.

It is not possible at present to decide if the two specimens of trematode belong to the same species or not without a full knowledge of the relationship and relative sizes of the genital organs of Nicoll's type. It is hoped that some other observer having access to the type will decide that question.

I am indebted to Prof. Leiper for various helpful suggestions during the study of this parasite.

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Journal of Helminthology, vol i., pp. 35-45.

Some new and little known Helminths from British Guiana.

By G. M. Vevers, M.R.C.S., L.R.C.P., F.Z.S.
Beit Memorial Research Fellow.

While engaged on work with the Filariasis Commission in British Guiana in 1921, under the direction of Professor R. T. Leiper, the writer had occasion to examine a number of birds and mammals, and from these eleven species of Entozoa were collected. Three species are new to science, and one of these, an Oxyurid from *Pithecia monachus*, has been placed in a new genus *Trypanoxyuris*.

NEMATODA.

Anisakinæ, R. & H., 1912, Emend, Baylis, 1920

Contracæcum andersoni, sp. n.

Host. *Florida caerulea*, Little Blue Heron (locally, " Blue Gaulding ").
Habitat. Small intestine.
Locality. Georgetown, B. Guiana.

Body cylindrical, tapering at both extremities. Cuticle transversely striated, the striations at the middle of the body being .003 mm. apart. Head .4 mm. wide, .16 mm. long. The head is formed by three fleshy lips and three large interlabia. Each lip bears two double papillæ. The interlabia are triangular in shape, .15 mm. in length, and have no papillæ.

The œsophagus is 3.75 mm. long with an average diameter of ·15mm. At the junction with the chyle intestine a solid posterior appendix is given off, measuring .75 mm. in length and .15 mm. in breadth. The intestine gives off an anterior cæcum, measuring 2.75 mm. in length; this runs forward alongside the œsophagus. The nerve ring is .325 mm. from the anterior end of the body.

Male.—15-17 mm. long, .35 mm. in diameter. The tail is short and conical, and is curved inwards towards the ventral surface. The ano-genital orifice is .085 mm. from the posterior extremity.

The papillæ are arranged in three groups: (1) Five pairs of postanal arranged in two ranks, the anterior pair being a double papilla; (2) Five pairs of adanal; (3) Twenty to twenty-five pairs of pre-anal, arranged

in two long rows. The spicules are similar and equal, measuring 1 mm. in length, and in the three males examined were not exserted from the ano-genital aperture. They are of an average thickness of .01 mm. throughout their length, except at the distal extremity, where they taper into a sharp point.

Female.—19-22 mm. long and .75 mm. in diameter.

The posterior extremity is conical and sharply tapering. The anal

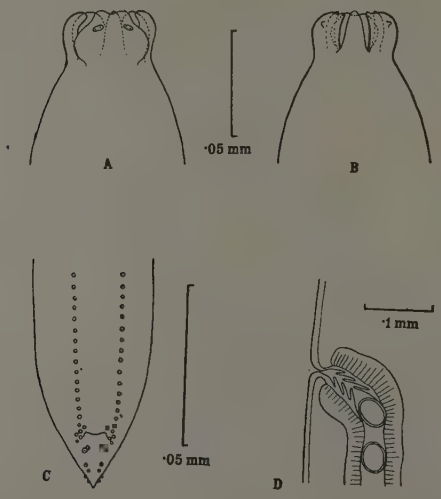

Fig. 1. Contracæcum andersoni, sp. n.
a. Head, dorsal aspect.
b. Head, lateral aspect.
c. Male, caudal end.
d. Female, vagina showing position of the valves.

orifice is .13 mm. from the posterior end of the body. The vulva is situated just anterior to the middle of the body ; in a worm, 20 mm. long, it was found at a point 9.5 mm. from the anterior end. The vagina is short and muscular and .15 mm. long ; it is provided with three pairs of leaf-like valves, which have their free ends directed forwards.

The eggs are oval in shape and are covered with a thick shell, which has a mosaic appearance. They measure .055 mm. × .045 mm.

This parasite was collected by Dr. John Anderson, and I have named it after him.

PORROCÆCUM DEPRESSUM (Zeder, 1800) Baylis, 1920.

Host. *Accipiter bicolor.* Red-legged Sparrow Hawk.
Habitat. Small Intestines.
Locality. Hossororro. N.W. District, B. Guiana.

HETERAKINÆ, R. & H., 1912.

ASCARIDIA TRUNCATA (Zeder, 1803) Dujardin, 1845.

Host. *Amazon ochrocephala.* Amazon Parrot. Locally, "Screeching Parrot."
Habitat. Small intestine.
Locality. Wauna Creek, N.W. District, B. Guiana.

ZEDER (1803) described a parasite from *Psittacus pulverentulus*, which he named *Fusaria truncata*. This was redescribed by Dujardin (1845), who transferred it to the genus *Ascaris*, creating a new sub-genus, *Ascaridia*, for this form. Railliet and Henry (1912) raised this sub-genus to generic rank, making *A. truncata* the type of the genus.

Travassos (1913) described what he took to be *Ascaridia truncata* from 17 different species of Psittacidæ from Brazil.

Clayton Lane (1917) compared *A. truncata* Travassos, 1913, with *A. truncata* Zeder, 1803, as redescribed by Dujardin. He concluded that they were different species. Moreover, he considered that in all probability Travassos had overlooked a bulb in the œsophagus in the male from which he figured the tail, and that, therefore, *A. truncata* Travassos, 1913, was not a member of the Genus *Ascaridia* Dujardin, but should be placed as a second species in a new genus, *Gireterakis* Lane, 1917, with *Gireterakis girardi* from the Bengal porcupine as the type.

From the small intestine of a "Screeching Parrot" (*Amazona ochrocephala*), shot by Mr. G. E. Bodkin, I collected a male and female, which agree with the description of *A. truncata* Travassos, 1913, in all respects save that of size, the measurements of my worms agreeing more closely with those given by Dujardin for *A. truncata* (Zeder, 1803).

The accompanying table gives the measurements of Dujardin and

Travassos compared with those of my material from *Amazona ochrocephala* :—

	Dujardin.	*Travassos.*	*Vevers.*
Width of head	0.28	0.38	0.4
Œsophagus, length ...	2.4	1.58	2.5
Œsophagus, breadth ...	0.28	—	0.3
Male.			
Length	52	25.3	43
Breadth	1.4	—	1.5
Anus from tip of tail ...	0.6	0.43	0.65
Spicules, length	2.2	2.3	2.3
Papillæ	1 or 2 pairs	15 pairs	15 pairs
Female.			
Length	63	27–32	55
Breadth	1.7	0.86	2
Anus from tip of tail ...	1.3	—	1.1
Vulva from head	34	Middle	divides body as 10.11
Eggs, length	0.069-0.071	0.081	0.075

From this table it will be seen that my form from *A. ochrocephala* in measurements is intermediate between *A. truncata* (Zeder, 1803), as redescribed by Dujardin, and *A. truncata*, Travassos, 1913.

A comparison of the male tail of my form with the drawing of the male as given by Travassos, shows that they agree in every respect, both as to the number and disposition of the papillæ, and also as to the length of the spicules. The differences in the length of the body cannot be taken as indicating any specific difference, as this only indicates a variation in degree of growth, or a host difference. One is, therefore, led to the conclusion that the form from *A. ochrocephala* is identical with that described by Travassos from various Parrot hosts in Brazil.

An examination of the œsophagus of both male and female forms from *A. ochrocephala* reveals a simple muscular œsophagus, with no sign of a bulb. We may, therefore, assume that Travassos was right in assigning his form to the Genus *Ascaridia*. Moreover, as the range of variability of a single species occurring in many hosts is very wide, we may consider him right in diagnosing his specimens as *Ascaridia truncata*

(Zeder, 1803). It is true that Dujardin gives the number of papillæ as "one or two pairs," but in doing this he in all probability only noticed the two large and prominent pairs of papillæ and overlooked the 13 small and inconspicuous pairs.

OXYURINÆ Hall, 1916.

Trypanoxyuris trypanuris. g. et. sp. n.

Host. Pithecia monachus. Humboldt's Saki. Locally, "Hura monkey."

Habitat. Cæcum.

Locality. N.W. District, B. Guiana.

Generic diagnosis.—Oxyurinæ: Mouth with two inconspicuous lips. Œsophagus, with a very distinct bulb. Male very much smaller than female, provided with one spicule and five pairs of papillæ, including one large pair preanal, which carry out a cuticular expansion round the candal end. At the extremity of the tail is a short sharp spike. The female is over three times as long as the male in the type species. The vulva is situated at the junction of the middle and anterior thirds of the body.

The eggs are slightly flattened on one side and contain an imperfectly formed embryo.

Type, Species.—Trypanoxyuris trypanuris. sp. n.

Specific diagnosis.—Trypanoxyuris.—Small fusiform worm, white in colour. The cuticle is transversely striated, except at the extreme anterior end, which is quite smooth. There is a slight cuticular expansion at the head end.

The nerve ring is situated at the junction of the middle and anterior thirds of the œsophagus proper. The œsophageal bulb is very distinct from the œsophagus, the portion joining it to that organ being very narrow.

Male.—The male is very small in comparison to the female, being 2 mm. long by .15 mm. in diameter. In the single specimen collected the anterior and caudal ends of the body were bent ventrally. The striations on the cuticle are .007 mm. apart at the anterior end and .01 mm. apart at the posterior end.

The œsophagus proper is .3 mm. long (about $\frac{1}{6}$ of the body length) and .05 mm. broad. The œsophageal bulb is .075 mm. in diameter.

The posterior end of the male terminates somewhat abruptly in a rounded extremity in the centre of which is a sharp spike, .012 mm. in length.

There are five pairs of papillæ in all; two preanal and three postanal. The larger pair of preanal papillæ carry out a cuticular expansion, which surrounds the tail end of the worm.

A single spicule is present .07 mm. in length. There is also present a

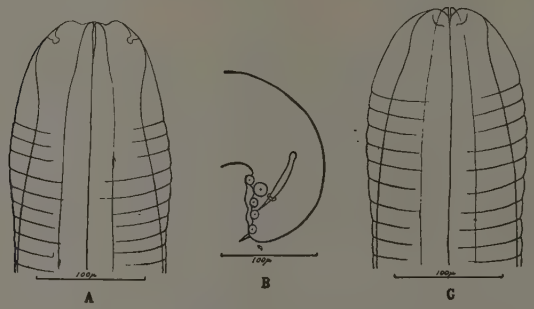

Fig. 2. *Trypanoxyuris trypanuris*. g. et. sp. n.
a. Head, dorsal aspect.
b. Male caudal end.
c. Head, lateral aspect.

chitinous annular gubernaculum.

Female.—The female is 6.7 mm. long by .6 mm. in maximum diameter. The œsophagus proper is .9 mm. long ($\frac{1}{7}$ of the length of the body) and the œsophageal bulb is .15 mm. in diameter.

The articular striations at the anterior end are .012 mm. apart, the space increasing to .015 mm. at the posterior end.

The tail is gently tapering and ends in a blunt point, the distance from the anus to the tip of the tail is .775 mm. The vulva is situated 2.4 mm. from the anterior end of the body at the junction of the middle and anterior thirds. The eggs are oval, slightly flattened on one side, and measure on an average .045 mm. × .03 mm.

I am indebted to Mr. R. I. Pocock, F.R.S., who identified the host of this parasite from skins which I prepared.

SPIRURINÆ Railliet, 1915.

SPIROPTERA NEOPLASTICA (Fibiger & Ditlevsen, 1914).

Host. *Mus decumanus.*

Habitat. Stomach wall.

Locality. Georgetown, B. Guiana.

This parasite was present in the stomach wall of nearly all the rats examined from the precincts of the Colonial Hospital, Georgetown. The common occurrence of the intermediate host, *Periplaneta americana*, would account for this. A useful method of obtaining the worms whole is, perhaps, worth noting. The worms are easily noticed in the stomach wall as thin tortuous threads just under the mucous membrane, a small pore is usually present at one end which gives the worm access to the stomach cavity. If the fresh stomach containing living worms be removed and placed in 1 per cent. Saline, in the course of an hour, or thereabouts, the worms will be found to have made their way out of the stomach wall and are floating free in the Saline.

CESTODA.

ANOPLOCEPHALINÆ R. Blanchard, 1891.

PARONIA VARIABILIS (Fuhrm., 1904) Fuhrm., 1921.

Syn. *Moniezia variabilis* Fuhrm., 1904.

Host. *Rhamphastos monilis.* Red-billed Toucan. Locally, "Bill-bird."

Habitat. Small intestine.

Locality. Wauna Creek, N.W. District, B. Guiana.

DAVAINEINÆ Braun, 1900.

RAILLIETINA Fuhrm., 1920. (*Skryabinia* Fuhrm., 1920.)

Fuhrmann (1920) divided up the old genus, *Davainea* Blanchard, which then contained 103 species, into four new Genera, retaining only seven species in the genus Davainea. In the same paper he called attention to the unsatisfactory way in which the family Davaineidæ had hitherto been classified by early writers upon the shape and number of the hooks and general external characteristics. He proposed a new classification almost entirely on two points: (1) The position of the genital pore in successive segments; and (2) The number of onchospheres contained by the egg capsules in the ripe segments.

For the largest of his four new Genera he proposed the name *Raillietina*, comprising 87 species, and this group he again subdivides into four sub-genera, *Paroniella*, *Ransomia*, *Skrjabinia* and *Johnstonia*. From the small intestine of a Spotted Sandpiper (*Actitis macularia*), shot near Georgetown, I obtained several specimens of a Cestode, which is apparently new and which may be placed into the Genus *Raillietina* (sub-genus *Skrjabinia*) Fuhrmann.

The generic diagnosis of *Raillietina* Fuhrmann, is that given by R. Blanchard for the old genus *Davainea* Blanchard, slightly modified ;—

" Cestoda-scolex, armed with a double (rarely single) crown of hooklets, small and of special shape. Suckers, more or less, round, surrounded by several rows of little hooks or spicules, which may fall off or persist through life. Genital pores unilateral or irregularly alternating. No uterus in the ripe segments, but parenchymatous egg capsules, each bearing one or more onchospheres."

The sub-generic diagnosis of *Skrjabinia* Fuhrmann may be translated as follows : *Raillietina* with genital pores irregularly alternating and Uterine capsules with a single onchosphere. Type, *Davainea cesticillus* (Molin).

Raillietina (Skrjabinia) Bodkini. sp. n.

Host. *Actitis macularia.* Spotted Sandpiper. Locally, " Sand Nit."
Habitat. Small intestine.
Locality. Georgetown, B. Guiana.

Average length of Strobila 50 mm. Head .135 mm. wide, provided with a rostellum and four suckers; the rostellum measures .1 mm. in length and .05 mm. in breadth ; the portion protruding beyond the head is .04 mm. long.

The rostellum carries one crown of 36 hooks; these are sickle-shaped with a very curved blade, and are .006 mm. in length. These hooks are very easily lost; only one specimen out of four examined retained a complete circle.

The suckers are .05 mm. in diameter, and armed with several rows of very minute spines.

A neck is present, .2 mm. long and .1 mm. broad ; segmentation starts immediately behind the neck. The young segments are .3 mm. broad and .04 mm. long ; the proportion of length to breadth gradually increases

until about the middle of the strobila the segments are square (.67 mm. × .67 mm.). After this the segments become increasingly longer until the ripe proglottids reach a length of 1.4 mm. and a breadth of .5 mm.

The genital pore is irregularly alternating in successive segments.

Male Organs.—In the mature segment the testes, which are scattered

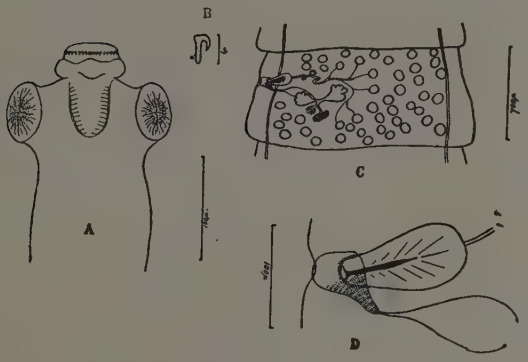

Fig. 3. *Raillietina (Skrjabinia) bodkini, sp. n.*
a. Scolex.
b. Hook from rostellum.
c. Mature segment.
d. Genital atrium and cirrus.

throughout the segment, number from 45-50, they are more or less circular in shape, with an average diameter of .05 mm. The vas deferens is slightly coiled and about .3 mm. in length. The cirrus is muscular, .12 mm. long by .06 mm. broad, it is armed at the distal end with numerous small spines. The cirrus opens into a slipper-shaped genital atrium, into the heel of which also opens the vagina; the portion near the vagina is studded with small spines which serve to engage the cirrus in copulation. The genital atrium is .09 mm. long and .05 mm. broad.

Female Genital Organs.—The vagina is short, .075 mm. in length; it opens into a large receptaculum seminis, .15 mm. long by .07 mm. broad.

This receptaculum seminis, as is seen in the more mature segments, is capable of great expansion, and becomes spherical, with a diameter of .175 mm. The ovary is bilobed, each lobe being on an average .1 mm. long and .06 mm. wide.

The shell gland lies posterior to the lobe of the ovary, which is nearest the genital pore. The yolk glands are gathered together in a small clump, which lies just below and median to the shell gland.

The ripe proglottids measure, on an average, 1.4 mm. long and .5 mm. broad; in them almost all trace of male genitalia is lost.

The egg capsules are oval, each measuring .03 mm. × .05 mm. They contain a single onchosphere, and are scattered throughout the parenchyma.

I have named this species after Mr. G. E. Bodkin, the Government Entomologist at Georgetown, B. Guiana, to whose assistance in the collection of material I am much indebted.

DIPYLIDIINÆ Stiles, 1896.

ANOMOTÆNIA MUTABILIS (Rud., 1819), Fuhrm., 1907.

Host. *Crotophaga ani.* Locally, "Old Witch."

Habitat. Small intestine.

Locality. Georgetown, B. Guiana.

ANOMOTÆNIA TRAPEZOIDES Fuhrm., 1906.

Host. *Urubitinga zonura.* Locally, "Chicken Hawk."

Habitat. Small intestine.

Locality. Abary Creek, B. Guiana.

HYMENOLEPIS PELLUCIDA Fuhrm., 1906.

Host. *Ostinops viridis.* Locally, "Green Bunyah."

Habitat. Small intestine.

Locality. Wauna Creek, N.W. District, B. Guiana.

TREMATODA.

ECHINOSTOMIDÆ Looss, 1902.

PARYPHOSTOMUM SEGREGATUM Dietz.

Host. *Catharistes fœtans.* Southern Black Vulture. Locally, "Carrion Crow."

Habitat. Small intestine.

Locality. Georgetown, B. Guiana.

HOLOSTOMIDÆ E. Blanchard, 1847.

HOLOSTOMUM VARIABILE Nitzsch, 1819.

Host. *Catharistes fœtans.* Southern Black Vulture. Locally, "Carrion Crow."

Habitat. Small intestine.

Locality. Georgetown, B. Guiana.

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Quiescence and Reviviscence in Nematodes, with special reference to *Tylenchus tritici* and *Tylenchus dipsaci*.

By T. Goodey, D.Sc.

Introduction.

During the past few years the writer has had an opportunity of making observations on the quiescent larvæ of *Tylenchus tritici* occurring in galls from ears of wheat, and of examining certain resting stages of *Tylenchus dipsaci* from diseased Narcissus bulbs.

The question of the number of years during which larvæ of *T. tritici* in wheat galls can retain their vitality and resume active movement after soaking the galls in water is a very interesting one, and is one that has attracted attention, from time to time, since Turberville Needham first noted the organisms, in 1743.

The present writer's observations are at variance with some of the findings of the earlist investigators, and it, therefore, seems desirable to give an account of these observations and review the whole question. In regard to the quiescent stages of *T. dipsaci* very little has, so far, been published, and the observations on these are put forward as an addition to our knowledge of the subject.

Tylenchus tritici.

As a preliminary, it may be well to explain that when wheat galls, caused by the parasitic nematode *T. tritici*, are soaked for some hours in water they swell up and finally liberate a creamy substance, which microscopically proves to be composed of thousands of larvæ of the parasite in the first stage of development. Such larvæ, if alive, are capable of intrinsic movement, and can swim in water, and are thus able to infect germinating wheat plants when galls are sown along with healthy seed.

It is this question of the power of intrinsic motility of the larvæ which is of prime importance, as on the presence or absence of this the larvæ must be judged to be alive or dead.

Bastian (1) p. 86, says: "It is an established fact that the young of

the so-called *Vibrio tritici* are capable of resuming their activity, by immersion in water, after having remained dormant within their seed-like gall for a period of twenty-seven years, since Baker was enabled to establish this fact, in 1771, with specimens given to him by Needham, in 1744."

Marcinowski (6) follows Bastian, and says that Baker was able to revive larvæ from galls stored for twenty-seven years. Baker's claim is contained in a letter from Needham (7) to l'Abbé Rosier. On page 227 this letter runs as follows: " L'espèce de vie dont ces vers sont doués et qui se conserve pendant des années dans un état parfait d'exténuation et de desèchement est très singulière. *M. Baker très-connu par ses observations microscopiques, avoit encore à Londres, en 1771, du bled rachitique que je lui avois donné en 1744 et qui présentoit fort peu de tems auparavant les mêmes phénomenes ;* cette vitalité si ferme et si durable, est une propriété qui me parôit d'une nature fort différente de la vitalité ordinaire."

In quoting the above, the important passage has been italicised, and it is obvious that it contains no mention of intrinsic muscular movement exhibited by the larvæ from the gall. Probably Baker and Needham considered that the larvæ were alive, but there is no real evidence in the passage quoted to show that they were.

It would seem that Bastian read into the passage sufficient to warrant him in saying that " it is an established fact that the young of the so-called *Vibrio tritici* are capable of resuming their activity by immersion in water, after having remained dormant within their seed-like galls for a period of twenty-seven years."

Davaine (4), p. 232, also quotes Needham on Baker's result.

Another worker with the galls from wheat was Bauer (2), whose work is referred to by both Bastian and Davaine. Bauer, p. 8, was able to obtain active larvæ by soaking galls, one lot of which had been kept for five years and eight months, and another lot for six years and one month. This worker paid particular attention to the motility of the larvæ ; in fact a good deal of his paper is devoted to a consideration of the number of times such larvæ could be brought into activity after drying and subsequent remoistening, having once been obtained from the galls.

Since Bastian's paper there appears to have been nothing of importance

written on the subject, the more recent writers merely cite the earlier findings.

The writer's experiments have been made with galls from various localities stored in tubes for different numbers of years. In most cases a number of galls belonging to a particular lot were put into water in glass capsules, four galls to each capsule, and allowed to soak for twenty-four hours. Each gall was then opened with needles, and the creamy mass of larvæ thus expelled into the water. Microscopical examination of these was made at once, and after the lapse of some hours. In all cases the capsules were kept at laboratory temperature for at least a week and examined daily for the presence of motility of the larvæ. Where no motility was found a drop or two of the water containing the larvæ was removed to a slide and carefully warmed to see if this would excite movement, and where this failed the larvæ were considered as dead.

Galls kept for two years.—Galls were removed from an ear of wheat which had been kept in a corked tube since September, 1920, when it was received from Prof. W. Somerville, of The School of Agriculture, Oxford. The galls were put into water in October, 1922, and after soaking, larvæ were liberated, of which about 50 per cent. showed motility.

Galls kept for six years.—These galls were taken from a stoppered jar in the collection of Prof. R. T. Leiper, and had been brought by him from Egypt in 1916. They were put in water in October, 1922, and about 50 per cent. of the larvæ showed motility.

Galls kept for nine years.—(*a*) These galls were taken from an ear of wheat which had been kept in a corked tube, bearing the date February, 1914, and the ear had, in all probability, been collected in August or September, 1913. It had come from Wisley, Surrey, and was originally the property of the late G. E. Johnson, M.Sc., whose promising career as a Helminthologist was cut short by his death in the war. None of the larvæ obtained by soaking these galls showed any signs of motility, even after gently warming. (*b*) In regard to this lot of galls, the evidence was sent to the writer by Mr. J. C. F. Fryer, Director of the Ministry of Agriculture and Fisheries, Pathological Laboratory, Harpenden. He soaked galls which had come from the harvest of 1913, and had been stored in a tube since 28th January, 1914. They were put into water in November, 1922, and after allowing the larvæ to stand in water for some days a small

proportion of them showed motility, especially on warming.

It thus appears that some larvæ within the gall remain reviviscent for a period of nine years. I am grateful to Mr. Fryer for sending me the above particulars of his tests.

Galls kept for 18 years.—One gall was taken from a tube containing three which had been stored inside a stoppered jar for 18 years by Prof. R. T. Leiper. Of the larvæ which issued on soaking in water, none showed signs of motility, even on warming.

From the above results one may reasonably draw the conclusion that larvæ within the galls may retain the power of reviviscence for a period of about nine years. This is the longest period of quiescence following which we have sound evidence of observed motility of the larvæ.

Tylenchus dipsaci.

(*a*) *From Diseased Onions.*—In March, 1920, soil in which onions had been grown suffering from the attack of *T. dipsaci*, was obtained from Mr. Arthur Amos, of the School of Agriculture, Cambridge. It had been stored in a dry condition in the laboratory for two years before the writer received it.

The soil was thoroughly mixed, put into pots, sown with onion seed and suitably moistened. In due course onion seedlings appeared, which showed pathological symptoms within ten days. On dissecting some of the distorted plants many *Tylenchus dipsaci* were found in an active condition, and there could be no doubt that they were the cause of the diseased condition of the seedlings. This result shows that *Tylenchus dipsaci* can remain quiescent in a dry soil for a period of two years, and then revive and parasitise a suitable host plant when the requisite conditions are present.

(*b*) *From Diseased Narcissus Bulbs.*—In September, 1920, a number of Narcissus bulbs attacked by *Tylenchus dipsaci*, were obtained from Mr. J. K. Ramsbottom, at Spalding, where he was carrying out the hot-water treatment for the cure of this disease on a large scale. Ramsbottom (8) has shown that the diseased bulbs frequently have masses of eelworms attached to the edges of the basal plate in the form of powdery concretions, cream or yellowish in colour, which are composed almost entirely of *Tylenchus dipsaci* coiled-up like watch springs. The nematodes having

thoroughly attacked the bulb, leave it towards the end of the storage period, and come to the outside of the bulb at the edge of the basal plate, and are thus in a position to migrate into the soil when such bulbs are planted.

Concretions from such bulbs were removed and placed in a small corked tube, and put aside for two years. In the autumn of 1922, and again in February, 1923, this tube was opened and small portions of the material were placed in water in glass capsules. Within ten minutes some of the coiled nematodes had uncoiled and straightened out, and within twelve to eighteen hours many of them were showing signs of intrinsic movement, which is different from the coiling movement. Many of the worms uncoil, but do not display any further motility. Quite 50 per cent. of the worms become actively motile within 24 hours of moistening, and had thus remained reviviscent for a period of two and a quarter years.

These quiescent nematodes present certain very interesting appearances. They are not first stage larvæ as are the larvæ of *Tylenchus tritici* within the wheat galls, but are probably larvæ in the last stage of development before becoming sexually mature. It is possible to differentiate males and females by the general shape of the tail region, and by the fact that the situation of the vulva is distinctly marked in the females. The internal structure is for the most part obscured by the abundance of granules with which the walls of the intestine are packed, and which are scattered in the region of the œsophagus. The structure of the œsophagus is not at all well defined in these forms ; they seem, in fact, to pass into the quiescent condition well stored with reserve-food granules and with the internal anatomy in that stage of transition which just precedes the final complete sexual differentiation.

They do not appear to be ensheathed, and in this respect differ from the quiescent stages of many of the nematodes parasitic in animals, for example, *Hæmonchus contortus*, *Nematodirus filicollis*, *Strongylus vulgaris*, and many others.

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Journal of Helminthology, 1923. *Vol.* I., *pp.* 53-60.

On the Intestinal Parasites of Sheep and other Ruminants in Scotland.

By T. W. M. Cameron, M.A., B.Sc., M.R.C.V.S.

Introduction.

Among all the domesticated animals sheep suffer most from parasitic diseases, and authorities are agreed that the steady loss to the country of sheep, mutton and wool is due mainly to animal parasites. The almost complete lack of knowledge of ovine parasites in Scotland prompted this enquiry, as until the species of parasites present and their distribution were known, little could be done to attempt a solution of the many questions of their life histories and the diseases they produce.

During the investigation occasional opportunities were found to collect helminths from cattle and goats. These are noted under the various parasites. The chief point of outstanding importance was the occurrence of *Monodontus trigonocephalus* in cattle.

As a basis for comparison it was decided to investigate and classify only the parasites of apparently healthy sheep slaughtered for food purposes.

Technique.

As the writer had to depend on the courtesy of the officials in charge of the slaughter-houses, butchers and others for his material, a technique had to be adopted which would not only cause them the minimum of inconvenience, but would do no harm to the intestines, which form a valuable by-product. The small intestine was detached from the large intestine (including the cæcum) and cleaned separately. A number of pails were filled with water, and the contents of the intestine forced into these by running the viscus between the fingers. This expelled all the parasites with the other material into the pail. A number of intestines treated thus were opened and found to be completely empty, and it is assumed accordingly that all were emptied. In case of doubt a stream of water was run through the intestine, and collected. The large intestine was easily everted and the contents washed into a pail. *Trichuris ovis* could then be picked off the exposed mucous membrane.

The contents of the pails were sedimented and decanted several times, usually about six, but depending largely on the nature of the intestinal contents. The residuum was finally stirred with water and passed through a nest of sieves. This nest was constructed on the lines of that used by Hall (1917). It contained six sieves 8 ins. square constructed of copper sides, with copper gauze bottoms, the meshes being 3, 6, 10, 16, 20 and 60 to the inch from the top downwards. The sieves were housed in a square oak framework, and any one could be pulled out without disturbing the others. At the bottom was a solid tray (not used in the present investigations) to collect eggs. The whole apparatus was contained in a wooden box with a handle.

The sieves were assembled, and the contents of the pail agitated and poured in at the top. They were allowed to drip and a pailful or two of water was gradually added to wash away debris. The coarse sieve at the top was mainly useful in retaining Cestodes and hard unbroken fæces.

Each tray was removed in turn and emptied into a large photographic dish. The Nematodes were picked out on a needle and fixed by dropping into hot alcohol and glycerine. They were examined in glycerine after evaporation of the alcohol.

That the sieves were effective in retaining all the parasites is shown by the fact that *Nematodirus* larvæ were retained in the bottom tray (60 mesh) while *Strongyloides* was retained by the last but one (20 mesh).

The parasites of cattle were collected in a similar manner, but owing to the large amount of intestinal contents only a few animals could be dealt with at any one time. Goats were only met with occasionally, and were treated individually.

The Endo-parasitic Fauna of Sheep in Scotland.

The following list of parasites was prepared from material collected from sheep slaughtered at the Edinburgh abattoir during the twelve months ending September, 1922. During this period some 700 sheep were examined.

Trematoda.

Fasciola hepatica can be found at all seasons of the year. It was the only fluke found by the author, although careful search was made for *Dicrocœlium dendriticum*. *F. hepatica* occurs also in goats and cattle in Scotland.

Cestoda.

Moniezia expansa and *M. planissima* were the only two tape-worms occurring at Slateford. Flatterly has recently (1922) reported *M. trigonophora* and *M. alba* from sheep in Britain, but although a large number of tape-worms was obtained and examined, only *M. expansa* and *M. planissima* were found by the writer. Ripe proglottides of these two species can be obtained throughout the year, although the heaviest incidence is in spring and summer. The number of specimens in a single host varies; in most cases only one worm is found, but in one healthy lamb killed at Turriff seven complete Moniezias were found.

Nematoda.

Ascaris ovis.—One specimen of this species, an immature female, was recovered at Slateford in May, 1922. It does not differ in any way from *A. lumbricoides* in man and the pig. It is generally accepted that we are dealing with *A. lumbricoides* in an unusual host.

Trichuris ovis.—This is a comparatively common worm in Scotland, occurring at all seasons of the year, but seldom are more than three or four specimens found in a single host. It is by no means so common in Scotland as it appears to be in England (Boulenger, 1914).

Capillaria longipes.—Six specimens of this parasite were collected in January, 1922, and one in May of the same year. It had previously only been recorded by Ransom (1911) in America.

Strongyloides papillosus.—This worm appears to be of infrequent occurrence in Scotland, and has only been found twice in this series.

Hæmonchus contortus has been found on various occasions in the Lowlands, and has also been found in goats on the Pentland Hills.

Ostertagia circumcincta and *O. trifurcata* were usually found in association with *Hæmonchus*, but always in small numbers.

Cooperia curticei.—This was the only species of *Cooperia* found. It is a fairly common parasite in Scotland. It has not been reported from England, Boulenger in 1914 recording only *C. oncophora*. This latter species does not seem to occur in Scotland. *C. curticei* also occurs in Scottish cattle.

Trichostrongylus vitrinus, T. extenuatus and *T. instabilis* occasionally occur, but always in small numbers.

Nematodirus filicollis and *N. spathiger*.—This is the commonest genus of *Trichostrongylidæ* in Scotland. Large tangled masses of the worm frequently occur in which one can distinguish males of both species. As the females are indistinguishable from each other it is impossible to give their relative frequency, but from a comparison of the males they seem to be present in about equal numbers. In spite of the large numbers found they appear to possess but little pathogenicity.

Oesophagostomum venulosum is a not uncommon parasite of the large intestine of sheep, in which it seems to cause no harm, either local or general. *O. colombianum*, the cause of "nodular disease," has not been found in Scotland, although *O. radiatum*, the cause of *bovine* nodular disease, was occasionally found in cattle at Slateford.

Chabertia ovina is an infrequent parasite of the large intestine of the sheep and goat.

Monodontus trigonocephalus, contrary to the view prevailing in the text-books, is of constant occurrence in Scotland. On every occasion on which collections were made, this parasite was found.

On four occasions this species was found in cattle slaughtered at Slateford. The numbers in these cases were 14, 26, 28, and 37 specimens respectively. This parasite has not been previously reported from cattle. Its occurrence in this host is of special interest as the accepted bovine species is *M. phlebotomus*. This latter was not found in Scotland. *M. trigonocephalus* is also found in the goat, several examples having been collected from these animals on the Pentland Hills.

Seasonal Distribution.

Collections were made periodically at Slateford from sheep slaughtered for food. At each visit 30 sheep were examined. The collections were made, as a rule, weekly or fortnightly, but for the sake of convenience the average for each month has been taken. In all about 700 sheep were examined. As these were drawn from all parts of Scotland they may be regarded as giving a fair indication of the seasonal variation for the whole country.

Owing to their infrequent occurrence, the other parasites are not included in the table. Although cestodes were continually met with, it was impossible to ascertain their numbers as the heads were usually absent, and the remainder of the strobile broken into pieces.

	Monodontus trigonocephalus.	*Chabertia ovina.*	*Oes. venulosum*	*Nematodirus*	*Cooperia curticei.*	*Trichuris ovis.*
January ...	130	1	2	66	15	6
February ...	28	—	—	3	—	—
March ...	99	2	2	2	3	1
April ...	92	2	1	31	2	4
May ...	80	—	9	109	1	1
June ...	86	4	10	203	16	15
July ...	155	1	—	91	3	6
August ...	98	3	—	35	1	3
September	139	3	11	71	—	11
October ...	81	—	1	—	—	4
November	66	—	—	75	—	1
December...	112	—	6	76	2	19
Average per month ...	97	1	3·5	60	3·5	5
Average per sheep examined	3	—	—	2	—	—

It will be noticed that by far the commonest parasite found is *Monodontus trigonocephalus*. In this species copulating forms were practically limited to May and June. During the latter month nearly all the specimens found were in copula.

Nematodirus sp. is very common, and can usually be found in tangled threadlike masses. *Cooperia curticei* is also of frequent occurrence, but its numbers are never very large. The other nematodes vary greatly, but none were ever found in large numbers.

Geographical Distribution.

The heavy incidence of hookworm recorded from Slateford raised the query as to the source of the parasite. The known pathology of the allied worms in man and the dog suggested that this worm might be of considerable economic importance in the sheep. Accordingly it was thought desirable to attempt to trace the locus of the infection. For this purpose Scotland may be divided into the following natural regions :—

I. Southern Uplands with—
  (*a*) S.W. Coastal plain.
  (*b*) S.E. Coastal plain.
II. Lowland belt and Fife.
III. Central Highlands.
IV. N.E. Coastal plain.
V. Northern Highlands.
VI. N. Coastal plain.

Each district is more or less self-contained, but within each there is a constant interchange of sheep. Accordingly, it was assumed that if a

flock in any district could be shown to harbour the parasite, the whole district could be regarded as infected. In each area a central town was selected and visited. Local sheep were examined at the various slaughter-houses. Only sheep which were known to have been born and fed in the district were of use. This increased the difficulty and lessened the number of sheep available for the enquiry, but the willing assistance of the local authorities helped to overcome this.

The following were the towns visited and the result of the examination in each case :—

Northern Highlands	16/8/22	Kyle	S	(19 M.).
	15/8/22	Wick	S	(4 M.) (3 M., 6 Ch.) (21 M., 2 Ch., 6 Oes.).
N.E. Plain ...	10/8/22	Turriff ...	S	(4 M.) (7 M.) (9 M.) (9 M.).
			s	(1 Moniezia) (21 N.) (? N.).
Central Highlands	14/8/22	Inverness ...	S	(6 M.) (8 M.).
	8/8/22	Braemar ...	S	(6 M.) (none).
	14/1/22	Perth	S	(13 M.) (16 M., 4 Ch.).
	18/8/22	Fort William ...	S	(7 M.) (10 M.).
	21/8/22	Inveraray ...	S	(10 M.) (10 M.) (10 M.) (11 M.).
Fife	5/8/22	St. Andrews ...	S	(6 M.) (7 M.) (15 M.) (14 M.).
Lowlands	6/2/22	Glasgow (Lanark)	S	(15 M.) (17 M.) (23 M.).
	22/8/22	Stirling (Central)	S	(31 M.) (21 M.).
	2/19/22	Edinburgh (Pentlands)	S	(7 M., 3 Ch.) (16 M., 1 Ch.).
Southern Uplands	1/9/22	Hawick ...	S	(8 M.) (9 M., 4 Ch.).
			s	(1 H.C.).
	4/9/22	Selkirk... ...	S	(5 M ., 1 Ch.).
S.W. Plain ...	10/7/22	Maybole ...	S	(16 M.).
S.S.W. Plain ...	12/7/22	Stranraer ...	S	(5 M.), (6. M.) (none).
S.E. ,, ...	4/19/22	Berwick ...	S	(4 M.) (19 M.).

(Each pair of brackets represents one animal and the figures the number of parasites recovered from it. M.= *Monodontus;* Ch.= *Chabertia;* N.= *Nematodirus;* H.C.= *Hæmonchus;* S.=Adult Sheep; s.=Lamb).

In addition, the following places were visited or specimens previously collected at these localities were placed at the writer's disposal by Prof. Ashworth.

Arrocher	s	(30 H.C.) (14 H.C., 8 *Ostertagia*) (10 H.C., 6 *Ostertagia*). (14 H.C., 20 *Ostertagia*).
St. Mary's Loch	s	(21 H.C., 16 N., 7 *Ostertagia*).
Roxburgh	s	(3 H.C.).
Bangor	?	M., Ch., *Ostertagia*.
Kelso	?	M., Ch., H.C., *Ostertagia*.

Forty sheep were examined in this part of the enquiry ; of these 38 harboured hookworms. The maximum number in any one sheep was 31, while the average figure was 10·5. All of these were healthy sheep slaughtered for food purposes. In the 12 lambs examined here and 18 examined at other times no specimens of *Monodontus* were found.


SCOTLAND
WICK
N.H.
N.E.P
INVERNESS
TURRIFF
KYLE
BRÆMAR
H.
FORT WILLIAM
PERTH
INVERARAY
ST. ANDREWS
L.
STIRLING
E.P.
EDINBURGH
GLASGOW
BERWICK
S.U.
SELKIRK
MAYBOLE
HAWICK
W.P.
STRANRAER

The results of this examination are plotted on the map. In every district *Monodontus trigonocephalus* was found, and there can be no doubt that it is not confined to any one spot but occurs all over Scotland.

Conclusions and Summary.

1. From an examination of over 700 sheep of Scottish origin a list of the parasites found in the intestinal tract has been prepared.

2. The commonest parasite found is *Monodontus trigonocephalus*, a worm which occurs also in goats and cattle. This parasite can be found at any season.

3. *Nematodirus* sp. also is extremely common during the warmer months.

4. From a systematic geographical examination of sheep it has been ascertained that *Monodontus trigonocephalus* occurs in every district in Scotland ; and of 40 sheep examined in this part of the enquiry, 38 were found to be infected. Thirty specimens have been recovered from an apparently healthy sheep, but usually the number is much smaller (7-10).

Acknowledgments.

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The writer has to acknowledge his indebtedness to Mr. J. Howard Jones, Veterinary Superintendent of the Slateford Abattoir, for permission to use the slaughter-house for collecting and the veterinary laboratory for preservation purposes. He has also to thank Dr. Hesse for assistance in the actual collecting and Prof. J. H. Ashworth for advice and encouragement during the enquiry.

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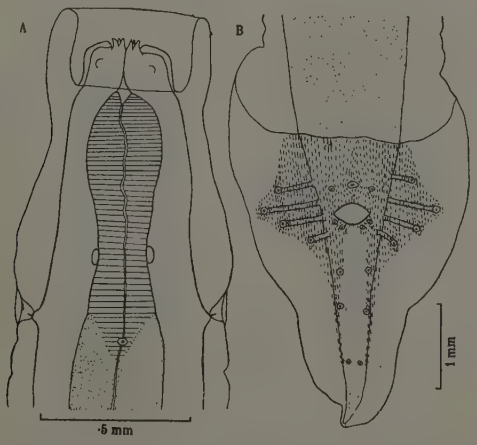
Two new Nematodes, collected in the Zoological Gardens of London.

By R. J. Ortlepp, M.A., Ph.D.

Physaloptera cebi. sp. n.

Host: *Cebus fatuellus*. *Habitat:* Stomach. *Locality:* South America. Two males and two females were collected from the stomach of a Brown Capucin. The two males are respectively 37 and 41 mm. long by 1.5 and 1.65 mm. thick; the two females are respectively 54 and 60 mm. long by 2.9 and 2.75 mm. thick in their posterior third.



Physaloptera cebi sp. n. (A) Cephalic extremity, ventral view. (B) Caudal extremity of Male.

The anterior part of the body is much attenuated, and the cuticle surrounding the cephalic extremity is slightly swollen and is completely reflected over the lips.

The two lateral lips are more or less rectangular in side view; they are from .132 to .15 mm. high and each carries on its summit a group of

four large and conspicuous teeth of equal height (.033 mm.), one external and three internal. No other teeth are present.

The cervical papillæ are small and are lodged in deep cuticular pits; they are situated at the level of the junction of the glandular and muscular œsophageal parts or just posterior to it. The excretory pore opens to the exterior a very short distance posterior to the cervical papillæ.

Female.—The vulva opens in a depression of the cuticle, and is situated in front of the posterior extremity of the œsophagus; in the 54 mm. long female it is found 6.6 mm. in front of the end of the œsophagus. The ovejector is straight, and is just over 3 mm. long; it is not distinctly divided into an anterior vagina and a posterior egg-chamber, the whole organ having a more or less uniform thickness of about .15 mm. From its posterior end there arise three uteri, all at the same level; these pass down the body and are filled with oval and thick-walled eggs, averaging .043 mm. long by .034 mm. thick.

Male.—The caudal expansions are well developed, and are supported by the usual four pairs of stalked papillæ of which the second pair from the front is the longest. The three pre-anal ventral papillæ are situated nearly in a line, the median papilla being the largest. There are five pairs of post-anal papillæ; the first and second pairs are situated immediately behind the anus, two of these papillæ being situated on either side of its postero-lateral border; the third pair is situated at the junction of the 1st and 2nd tail quarters, the fifth at the junction of the 2nd and 3rd tail thirds, and the fourth pair is found between these two pairs it being, however, nearer the third than the fifth pair.

The spicules are equal and curved, the right ending in an obtuse point, whereas the tip of the left is acute; both are .6 mm. long, the right being .07 mm. thick at its base and the left .065 mm.

The ventral surface of the tail is covered with coarse tubercules extending down to the fifth pair of post-anal papillæ; the area between the post-anal papillæ is devoid of these tubercles.

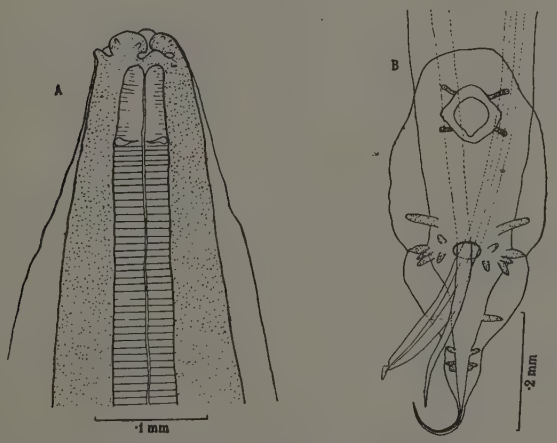
HETERAKIS INTERLABIATA. sp. n.

Host: Rhizothera longirostris. Habitat: Cæca. *Locality:* Malacca.

Length of male 7 mm. by .3 mm.; female 8-9.5 mm. by .36-.4 mm.

Laterally there are two well developed and conspicuous alæ, commencing a short distance posterior to the anterior extremity and extending into the posterior half of the body. Cervical papillæ are absent.

The three lips are each cut in at their base; the dorsal carries two papillæ, and the other two carry one median papillæ each; between each pair of lips there is a small and inconspicuous interlabium.



Heterakis interlabiata sp. n. (A) Cephalic extremity, dorso-lateral view. (B) Caudal extremity of Male.

Female.—The vulva is situated at about the middle of the body. The tail is long and pointed, the eggs oval, measuring .066 mm. long, .037 mm. broad.

Male.—The male caudal expansions extend across the ventral surface in front of the chitinous sucker. There are twelve pairs of caudal papillæ, namely, two pairs round the sucker, six pairs circumcloacal, four pairs of which are lateral and two pairs ventral in position, and the remaining four pairs are post-anal; the most anterior pair of these last is long, and is situated at the junction of the 1st and 2nd tail thirds, the remaining

pairs being found at about the centre of the middle third of the tail; the tail portion posterior to these last papillæ tapers gradually to form a long and filiform termination.

The spicules are equal or slightly sub-equal; the leftis flanged, and it is characteristically notched in a manner similar to that found in *H. papillosa;* the right spicule tapers to an acute tip; both are about 1.25 mm. long.

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Description of *Capillaria leucisci*, n.sp., found in the Intestine of *Leuciscus phoxinus* Linn.

By A. J. Hesse, B.Sc., Ph.D.

Introduction.

The nematode described in this paper was obtained from the minnow, *Leuciscus phoxinus* Linn. About 50 minnows were caught in Loch Lubnaig in Perthshire, Scotland. Only two specimens were infected, one with a single female, the other with two females and a male. The worms were found in the mucus of the posterior part of the intestine.

The work has been done in the Department of Zoology of The University of Edinburgh, and I am indebted to Professor J. H. Ashworth for advice during its progress, and to Dr. N. Annandale for the name of the fish.

The genus Capillaria was established in 1800 by Zeder on material from poultry. The type species is *Capillaria* (Trichocephalus) *anatis* (Schrank, 1790) from ducks. The five species of *Capillaria* thus far described from fish are :—

Nematode.	*Host.*
1. *Capillaria tomentosa*, Duj., 1843.	Scardinius erythrophthalmus L. Idus melanotus, Heck.
2. *Capillaria gracile*, Bellingh, 1844.	Merlucius vulgaris Cuv.
3. *Capillaria brevispicula*, O. von Linst., 1873.	Blicca bjoerkna Linn.
4. *Capillaria fritischi*, Fritsch, 1886, Trav., 1914.	Malapterurus electricus Linn.
5. *Capillaria tuberculata*, O. Von Linst, 1914.	Acipenser ruthenus Linn.

Morphology of C. leucisci, n. sp.

The worms are threadlike, and possess the characteristic form of Capillaria, increasing gradually in diameter from the anterior end to the posterior end without marked increase in the post-vulvar region. The

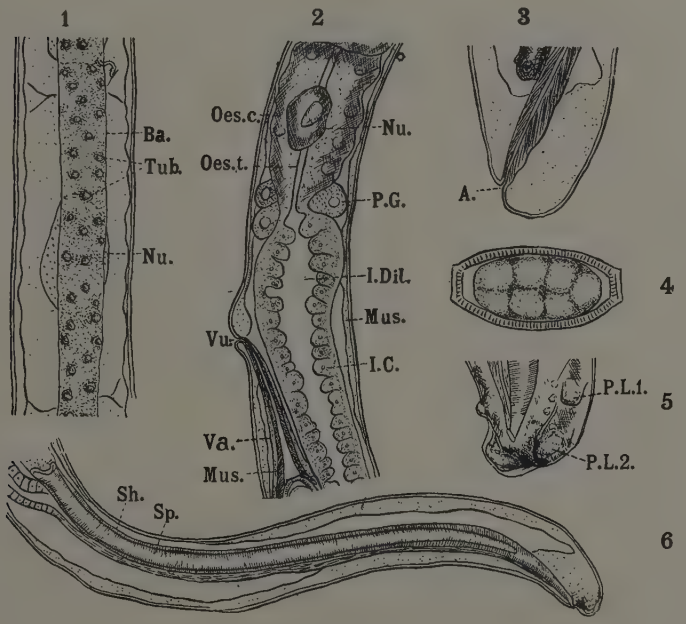
œsophageal region is shorter than the post-vulvar region. There passes down on each side a band, which is darker and more granular than the rest of the body. The bands begin about .1 mm. behind the mouth, and extend to the posterior end. The breadth of the band, in the female, is about .017 mm. in the anterior region, and .028 mm. in the post-vulvar region, and .013-.015 mm. in the male.

Small wart-like tubercles are situated on these bands (Fig. 1), and, especially in the case of the female, increase in prominence posteriorly in the region of the vulva, where they become very coarse. Further back they gradually decrease in size and become wider apart, and disappear altogether a short distance behind the vagina ; the band only persisting as a dark strand. Some of the tubercles are in rows, but others are irregularly situated. If the worm, especially the female, be rolled so that it lies on its ventral surface, the tubercles are seen as small projections. The cuticle of the body is smooth.

Alimentary Tract.—The mouth leads into an inconspicuous buccal capsule, the wall of which is chitinous. No papillæ were observed. The lumen of the capsule leads into a wavy tube, about .3-.4 mm. long in the female, which is not surrounded by cells. The tube is continuous with the lumen of the œsophagus, which lined with chitin passes through a string of vacuolated œsophageal cells. The cells are comparatively large with crenulated margins, and their large nuclei contain refringent bodies. The length of the cells varies from .07-.12 mm., and their breadth from .027 mm.-.04 mm. The diameter of their nuclei varies from .02-.05 mm., the œsophageal region is about 3 mm. long in the female and 1.5 mm. in the male. At the beginning of the post-vulvar part of the body the œsophagus passes into the dilated anterior part of the intestine, which consists of a single layer of cells, roughly hexagonal in form when viewed from the dorsal surface. The intestine takes an almost straight course, and passes into a muscular rectum, which opens by the anus subterminally. In the living condition the worm is whitish and resembles a fine piece of cotton. In the mucus of the intestine the male was spirally coiled and difficult to remove, and the three females were sinuous in form. The œsophageal region of the female was generally loosely coiled, and the extreme posterior end straight or only slightly bent.

The male is much smaller than the female, having a length of about 3.38 mm. and a breadth of about .047 mm. in the testicular region, and about .04 mm. at the posterior extremity in the region of the spicule. The posterior extremity is slightly bent ventrally.

There is a single coiled testis, which is bulky, occupying most of the



Capillaria leucisci n. sp.

(1) Anterior region showing tuberculated lateral band and œsophageal cells. Ba.=band; Tub.=tubercles; Nu.=nucleus of œsophageal cell.

(2) Region of junction of œsophagus and intestine. Oes.c.=œsophageal cell; Oes.t.=lumen of œsophagus; P.G.=pyriform gland; I.dil.=intestinal dilatation; I.c.=intestinal cell; Vu.=vulva; Va.=vagina; Mus.=musculature.

(3) Posterior end of female. A=anus.

(4) Egg.

(5) Tail of Male. P.L.1, P.L.2=posterior lobes.

(6) Posterior end of Male showing Sp.=spicule and Sh.=spicular sheath.

posterior region. A single blunt spicule (Fig. 6) is present. The head of the spicule is about .013 mm. broad, and the length of the entire spicule is .26 mm., and the maximum breadth is .01 mm. The spicule is sur-

rounded by a sheath, about .013-.014 mm. broad, which is finely striated transversely. The sheath was not observed in an evaginated condition. The rectum is situated ventrally to the sheath and spicule, and opens by the same cloacal opening subterminally between the posterior lobes.

There are two posterior lobes (Fig. 5) supporting a feebly developed membranous expansion. Anterior to these lobes are two smaller supporting lobes, one on each side of the cloaca.

The female is only slightly coiled and longer than the male. It has a length of about 8-9 mm., and a breadth of about .013 mm. anteriorly, and a maximum breadth of .06-.07 mm. posteriorly. The posterior extremity is blunt and straight, or only slightly bent.

There is a single ovary, which begins in the rectal region and extends anteriorly ; it suddenly thins out and becomes bent on itself for a short distance, and then continues anteriorly again as a broad uterus filled with eggs. The uterus passes into a muscular vagina (Fig. 2, Va.), which opens by the vulva on a slight elevation about one-third of the length of the body from the anterior end. The junction of the œsophagus and the intestine is a little anterior to the vulva, and at this junction are situated the "pyriform glands." The intestine passes into a muscular rectum, .065-.07 mm. long, which opens by the anus subterminally about .013-.02 mm. from the posterior end.

The *egg* (Fig. 4) varies from a lemon shape to an oblong lozenge shape, with flattened poles. Some eggs are slightly constricted in the middle region, but not characteristically so. The outer shell is radially striated. The surface has a pitted appearance, due to little depressions.

The eggs in the distal part of the uterus show no embryos, and are probably deposited in an early stage of cleavage. The eggs in utero measure .06-.064 mm. in length, and .028-.03 mm. in breadth ; the shell is about .003 mm. in thickness.

(1) C. TOMENTOSA (Duj.).

Cuticle and Surface : Striated posteriorly.

Lateral bands : One longitudinal band, with tubercles anteriorly and hairs posteriorly.

Male : (Unknown).

Female : Head 0.009 mm. broad. Length 8.0-9.15 mm. Breadth 0.075 mm. Vulva 4.0 mm. from anterior end.

Egg : Granular and characteristically constricted in the middle. Length 0.06-0.064 mm.

Host : Scardinius erythrophthalmus and *Idus melanotus.*

(2) C. GRACILE (Bellingh).

Female : Length about one inch.

Host : Merlucius vulgaris.

(3) C. BREVISPICULA (v. Linst.).

Lateral bands : Two lateral bands and transverse folds in many places. Band is to breadth of body as 2 : 5.

Œsophagus and cells : Œsophagus in female $\frac{2}{3}$, in male $\frac{1}{2}$ of body length. Cells short and wider than long.

Male : Length 3.3 mm., maximum breadth 0.06 mm. Spicule 0.25 mm. long. Sheath smooth. Two posterior round lobes present.

Female : Length 7.8 mm., breadth 0.1 mm. Posterior end round.

Egg : (Unknown).

Host : Blicca bjoerkna and *Lota vulgaris.*

(4) C. FRITISCHI (Fritsch, 1886) Travas., 1914.

Cuticle and Surface : Papillæ scattered over body. Head possesses collar-like dilatations.

Male : (Unknown).

Female : Length 15 mm. Posterior extremity obtuse. Anus terminal.

Egg : Large and more developed than is usual for a *Capillaria* (Fritsch). Constricted in the middle (hour-glass shaped).

Host : Malapterurus electricus.

(5) C. TUBERCULATA (von Linst.).

Cuticle and Surface : Head round, with two papillæ.

Lateral bands : None.

Œsophagus and Cells : Œsophagus in male is to posterior part of body as 13 : 14. In female as 14 : 19.

Male : Length 5.81 mm. Breadth at anterior end 0.026 mm., at middle 0.066 mm., and at posterior end 0.036 mm. Spicule 0.44 mm. long and 0.0052 mm. broad. Sheath smooth and projects slightly over the spicule when evacuated. Two posterior lobes are present.

Female : Length 8.71 mm., breadth at anterior end 0.035 mm., at middle 0.092 mm., and at posterior end 0.07 mm.

Egg : Shell is thick. Length of egg 0.083 mm., breadth 0.026 mm.

Host : Acipenser ruthenus.

Conclusions.

A comparison of the six species of *Capillaria* from fish shows that there are six main points distinguishing the different species from one another :

(*a*) The nature of the cuticle.

(*b*) The presence or absence of bands, and of the structures on them.

(*c*) The length of the œsophagus, and the nature and size of the œsophageal cells.

(*d*) The length and shape of the spicule, and the nature of the sheath.

(*e*) The shape, nature and size of the egg.

(*f*) The different hosts.

By comparing the dimensions, it is evident that the females of *C. leucisci* and *C. tomentosa* practically correspond in size.

The points of difference which distinguish *C. leucisci* from *C. tomentosa* are :—

(*a*) The unstriated cuticle.

(*b*) The presence of *two* lateral bands with tubercles only.

(*c*) The size of the œsophageal cells (in comparison with Dujardin's drawing, where the cells are wider than long).

(*d*) The distance of the vulva from the anterior end.

(*e*) The absence of a distinct and characteristic constriction in the middle of the egg.

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Studies on two new genera and some little known species of the nematode family, *Trichostrongylidæ* Leiper.

By T. W. M. Cameron, M.A., B.Sc., M.R.C.V.S.

Introduction.

Six species of *Trichostrongylidæ* are described in this paper. Four are previously recorded species which were insufficiently known and described, viz. :—

Graphidium strigosum (Duj., 1845). R. & H., 1909.

Strongylus affinis Megnin, 1895. Type for *Graphidioides* nov.

Mecistocirrus digitatus (v. Linstow, 1906) Neveu Lemaire, 1914.

Strongylus torulosus Molin, 1861.

Two species are new to science, viz., *Molineus felineus* from *Felis yaguarundi*, and *Viannaia saimiris* from *Saimiris sciurea*.

The material, on which the description of the first and third species is based, was obtained from the Departmental collection. The remaining material was collected from animals which died at the Gardens of the Zoological Society of London.

The author desires to record the deep obligation he is under to Professor R. T. Leiper, and to thank him, not only for the material placed at his disposal, but also for his assistance and advice.

Graphidium Railliet & Henry, 1909.

The genus *Graphidium* was created by Railliet & Henry in 1909 to include the species *strigosum*, *affine* and *rudicaudatum*, with the following diagnosis :—

". . . . Cuticle with numerous longitudinal striations. Mouth large, supported by a chitinous ring resembling a mouth capsule. Caudal bursa with posterior rays rising in a common trunk, and anterior and posterior rays divided. Vulva in posterior third or quarter of body, covered or not by an appendix. Oviparous."

Type by designation. *G. strigosum*.

The type species occurs in the common rabbit in Europe, but has

never been completely described. The presence of well preserved material from British rabbits in Professor Leiper's collection has enabled the following account to be prepared :—

(1) *Graphidium strigosum* (Duj., 1845) R. & H., 1909.

Syn. :—*Strongylus retortæformis* Bremser, 1824 (nec Zeder, 1800).
Spiroptera leporum Moniez, 1880.
Strongylus blasii v. Linst., 1887.

Hosts : *Lepus cuniculus* and *L. europaeus ; Habitat :* Stomach and intestine. *Locality :* Western Europe.

In the fresh state the worms are blood red in colour, but on fixing in hot alcohol they become brownish or even colourless.

MORPHOLOGY.

They are long slender forms, which vary considerably in their dimensions. The male is about 8 to 16 mm. long and .18 to .3 mm. broad ; while the female is 10 to 20 mm. long and .19 to .5 mm. broad. The cuticle is conspicuously striated longitudinally—there being about 50 equidistant lines distributed around the circumference. There are also numerous fine transverse striations present, which, intersecting the longitudinal lines, give these a fine beaded appearance.

Cephalic extremity.—The anterior end is smoothly rounded. The cuticle is bent inwards to form a buccal cavity about .015 mm. deep. In optical section, this cuticle gives the appearance of two backwardly projecting teeth.

The œsophagus is straight, slender and tapers gradually towards its anterior end. It varies in length from .6 to 1 mm., and has a maximum diameter of .16 mm.

Two inconspicuous cervical papillæ are situated about the junction of the posterior and middle third of the œsophagus.

The nerve ring is inconspicuous, and is situated about the middle of the œsophagus.

The excretory pore lies between the nerve ring and the cervical papillæ.

The cephalic cuticle is normally not inflated, but occasional inflated specimens are found.

The Female.—The vulva is a prominent transverse slit, situated on a thickening of the cuticle about 4.5 mm. from the posterior end. The body is sharply reduced in thickness posterior to this point. The com-

plete muscular ovejectors are about 1.2 mm. long—although occasional longer forms are found. It is probable that the central portion (.5 mm. long) should be looked upon as a part of the vagina, while the two terminal portions (.35 mm.), which are separated from it by a slight constriction, form the ovejectors proper. The vagina is always directed posteriorly, forming an acute angle with the inferior ovejector. Both ovaries arise in the anterior portion of the body. The superior ovary pursues a con-

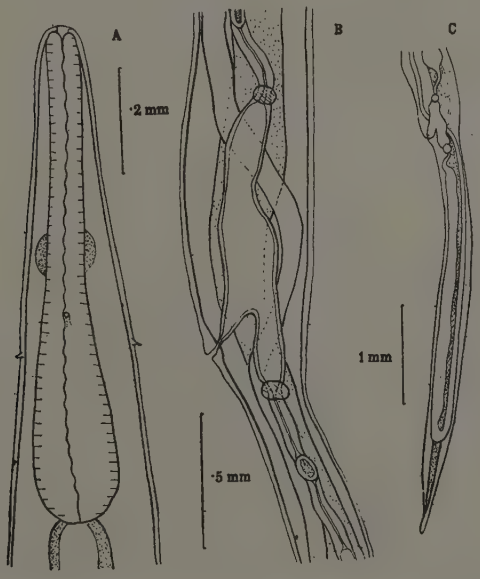

Fig. 1. *Graphidium strigosum.* (A) cephalic extremity; (B) ovejectors; (C) tail of female.

voluted course to join the superior ovejector, while the inferior ovary, rising a short distance posteriorly of the other, runs to within 1 mm. of the posterior extremity, where it turns and joins the inferior ovejector.

The inconspicuous anus is situated about .28 mm. from the posterior extremity. It joins the intestine by a short rectum.

The posterior extremity is bluntly pointed, and has a band of coarsely

striated cuticle (as in *Cooperia*). It is slightly constricted above this. The ova, embryonated when deposited, are .100 to .110 mm. long and .050 to .060 mm. broad.

The Male.—A pair of conspicuous *prebursal papillæ* occur about .04 mm. from the commencement of the bursa.

The testis and intestine are normal.

The bursa is found rolled on itself, and can only be unrolled with the greatest difficulty. It is laminated (as in *Hæmonchus*), and is very elastic. It is not divided into distinct lobes, but in the unrolled condition, the bursa is folded on either side of the dorsal ray to form a pseudo-dorsal lobe. This disappears on flattening out.

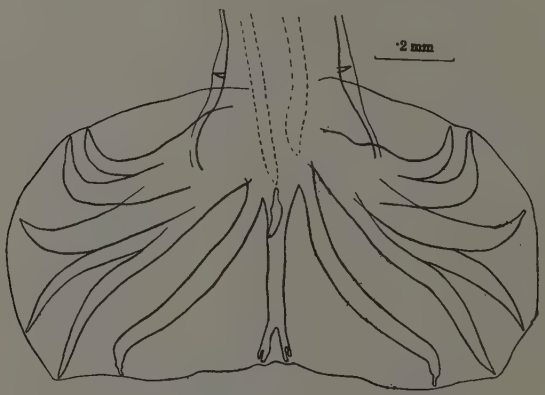

Fig. 2. *Graphidium strigosum*. Bursa, ventral view.

The disposition and relative size of the *rays* are shown in Fig. 2. The ventral rays rise in a common stem, and both bend sharply forward. The ventro-ventral ray is smaller than the latero-ventral. The lateral rays also originate in a common stem. The externo-lateral is about twice the thickness of each of the other laterals, and is directed slightly anteriorly. The medio- and posterio- lateral rays are directed posteriorly. The dorsal ray gives off long stout externo-dorsal rays, which terminate in crooked finger-like processes. The dorsal ray bifurcates near its tip—each bifurcation terminating in two digitations, the median of which

is the longer and ends in two papilliform processes. All the rays are sharply pointed and reach the edge of the bursa.

The genital cone is short, with apical ornimentations.

The accessory piece is about .13 mm. long by .03 mm. broad, and is situated close to the genital cone. It is colourless, but well defined.

The spicules are equal, long and filiform, and measure 1.5 to 2.5 mm. Each consists of two chitinised rods joined by a membrane. The distal terminations are multiple pointed and very complicated.

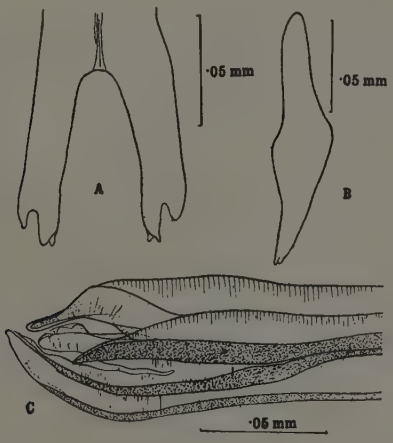

Fig. 3. *Graphidium strigosum.* (A) dorsal ray of bursa; (B) accessory piece; (C) distal end of a spicule.

Considerable variation in size takes place in this species.

PATHOGENICITY.

This worm is a blood sucker—and in addition to causing a gastritis, causes a severe anæmia and emaciation in rabbits.

GRAPHIDIOIDES. Gen. nov.

(2) GRAPHIDIOIDES AFFINIS (Megnin, 1895).

Host: *Dolichotes magellineus.* *Habitat:* Stomach. *Locality:* Argentine.

Strongylus affinis was described in 1895 by Megnin, and in 1906 by V. Linstow (under the name of *Strongylus rectus*). In 1909 Railliet & Henry

placed it in their new genus, *Graphidium*. It is proposed in this paper to make it the type of a new genus.

MORPHOLOGY.

In the fresh state the parasites are blood red in colour, but become brown on fixing in hot alcohol.

They are long slender forms. The male varies in length from 9 to 17 mm., with an average breadth of .3 mm. The female is 16 to 21 mm. long and about .5 mm. broad.

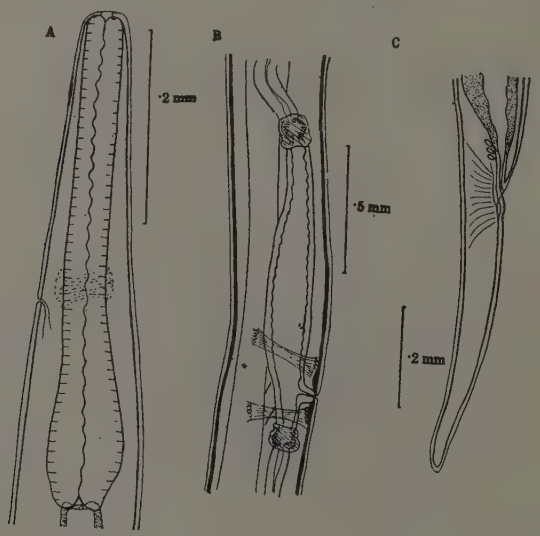

Fig. 4. *Graphidioides affinis*. (A) cephalic end; (B) ovejectors; (C) tail of female.

The cuticle is similar to that of *G. strigosum*.

The cephalic extremity.—This resembles the anterior extremity of *G. strigosum;* but the component parts differ. Four small circumoral papillæ are present. The œsophagus is more claviform, and is about .55 mm. long, with a maximum diameter of .1 mm. There are no lateral cervical papillæ.

The nerve ring is conspicuous, and is situated about the middle of the œsophagus. The excretory pore is situated at the level of the lower

border of the nerve ring. Cervical glands are present. Like *G. strigosum*, the cephalic cuticle is only occasionally swollen.

The female.—The vulva opens transversely, about 6 mm. from the posterior extremity. The body does not narrow immediately posterior of the vulva. The superior ovejector is very short, while the inferior is very long. Together they measure about 1.2 mm. The vagina is short, and always situated at right angles to the ovejectors. Four conspicuous muscle bands originate from the thickened cuticle surrounding the vulva to anastomose with the somatic muscles on the posterior side of the body.

The anus is situated about .5 mm. from the posterior extremity. It

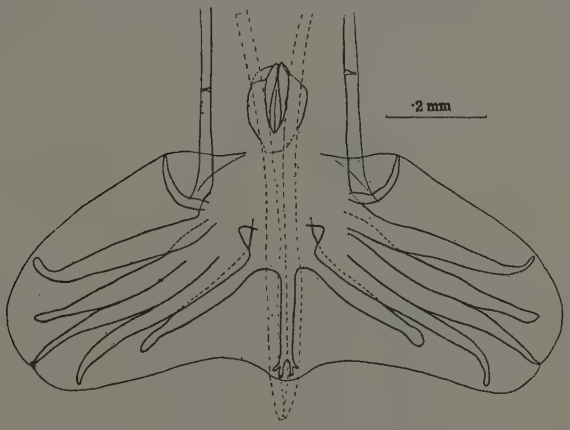

Fig. 5. *Graphidioides affinis*. Bursa, ventral view.

is conspicuous, and is protected by a small flap of cuticle. This has a semi-circular margin. A thickened portion of cuticle projects just posterior of this flap. The body is narrowed abruptly posterior of the anus.

The termination is bluntly pointed, but conspicuous transverse striations in this region are absent.

The ova are thin shelled, and measure about .14 mm. long by .075 mm. broad.

The Male.—A pair of inconspicuous prebursal papillæ are present, about .04 mm. from the anterior border of the bursa.

The bursa, which is much smaller than in *G. strigosum*, is also naturally rolled, but to a less extent than in that species, and is difficult to unroll.

It is not laminated, but is ornimented with cuticular bosses (as in *Nematodirus*). It is indistinctly divided into three lobes.

The disposition of the rays is shown in Fig. 5. The ventro-ventral ray is very small and is directed anteriorly. The latero-ventral ray is much larger and thicker, and is directed posteriorly with an anteriorly turned tip. The lateral rays are about equal in breadth. The externo-lateral ray terminates in an elongated swollen knob, while the medio- and posterio- lateral rays are sharply pointed. The posterio-lateral ray has a distinct shoulder near its origin. The externo-dorsal rays—given off from the main stem—have spatulate terminations and run parallel to the posterio-lateral rays. The somewhat slender dorsal ray bifurcates near its tip. The short lateral branches are directed outwards, while the longer median branches end in two digitations. All rays—

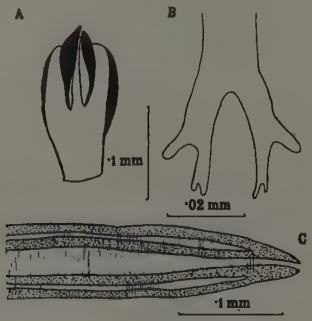

Fig. 6. *Graphidioides afficnis*. (A) acessory piece; (B) dorsal ray of bursa; (C) distal ends of spicules.

except the externo-lateral and externo-dorsal—reach the edge of the bursa. These two terminate a short distance from the edge.

The genital cone is short with concave sides.

The accessory piece is situated some distance anterior to the genital cone. It consists of a broad base with raised lateral edges, and a double central keel. The spicules lie between the keel and the raised edges. The shape and size of the accessory piece are somewhat variable. It is about .15 mm. long and .8 mm. broad.

The spicules are equal, long and filiform, with an average length of 2.8 mm. Each spicule consists of two chitinised rods, joined near the

tip. The posterior extremity is simple. The anterior extremity is united to two strands. From the median side of each spicule project two membranes which anastomose near the terminations of the spicules. These are, accordingly, virtually joined together.

Pathogenicity.

This worm was the cause of a fatal gastritis in a Patagonian Cavy. It attaches itself to the gastric mucous membrane.

Discussion.

This parasite differs from *G. strigosum* in many respects—notably by the absence of cervical papillæ, shape of bursa and disposition of ventro-ventral rays, shape of accessory piece and spicules, shape of ovejectors, vagina and posterior extremity of the female. These differences are so striking that it obviously cannot be retained in the same genus. It differs from most of the *Trichostrongylidæ* by the possession of long slender spicules and from *Nematodirus* and *Mecistocirrus* by the character of the dorsal and ventral rays. Accordingly it is proposed that this species should be made the type of a new genus, *Graphidioides* differing from other Trichostrongylidæ genera by the possession of long slender spicules with simple points, and widely diverging ventral rays. The type species is *Graphidioides affinis* (Megnin, 1895).

Graphidium rudicaudatus, R. & H., 1909, from *Viscacia viscacia*, from Argentina, resembles *G. affinis* very closely. It differs mainly by its smaller size, equal ovejectors, sharply pointed externo-dorsal ray and absence of an accessory piece. Its affinities to the type of *Graphidioides* are so close, that the latter point requires re-investigation. The other points are only of specific value, and it is proposed to include it in this new genus. Should the absence of an accessory piece be confirmed, its position would require re-determination.

Mecistocirrus Neveu Lemaire, 1914.

In 1906, v. Linstow, described *Strongylus digitatus*, from India. In 1912, Railliet & Henry created the new sub-genus, *Mecistocirrus*, of the genus *Nematodirus* to receive this species. Meanwhile *Strongylus fordii* was described by Daniels from Malay in 1908, and the following year

by Stephens (under the name of *S. gibsoni*). Leiper, in 1911, had expressed the opinion that this was the same as v. Linstow's species, but Railliet & Henry separated these two forms on the following not very important points :—

	M. digitatus.	*M. fordii.*
Length of spicule	... $\frac{1}{6}$ to $\frac{1}{5}$ of body length	... $\frac{1}{4}$ to $\frac{1}{3}$ of body length.
Length of bursa	... Twice breadth	... About equal to breadth.
Salient lobule of bursa at level of E.D. rays	Absent	... Present.

In 1912 Neveu Lemaire, from an examination of the female genital system, raised the sub-genus to generic rank. In 1922, Morishita described *M. tagumai* from Japan. His species differed from the others on the following points : Length of spicules, $\frac{1}{5}$ to $\frac{1}{4}$ of body length ; bursa slightly longer than broad ; salient lobule present but small. It will be noticed that this species is exactly intermediate between *digitatus* and *fordii*, and forms with them an unbroken series. Examples studied by the writer show that the salient lobule of the bursa disappears when the bursa is flattened out, while specimens with spicules $\frac{1}{4}$ to $\frac{1}{3}$ of the body length have a bursal length of twice its breadth. Accordingly there can be no doubt that Leiper's opinion was the correct one, and only *one* species exists. In 1919, Sheather described the same worm from India as " A new nematode, causing parasitic gastritis in calves," but was apparently unable to identify it.

(3) MECISTOCIRRUS DIGITATUS (v. Linstow, 1906) Neveu Lemaire, 1914.

Syn. :—*Strongylus digitatus* v. Linst., 1906.
Strongylus fordii Daniels, 1908.
Strongylus gibsoni Stephens, 1909.
Nematodirus digitatus (v. Linst.) R. & H., 1909.
Mecistocirrus fordi (Daniels) Neveu Lemaire, 1914.
Mecistocirrus tagumai Morishita, 1922.
Nematode Sp. nov. Sheather, 1918.

Hosts : Bovines ; Pig ; Sheep ; (Man ?) *Habitat :* Stomach and small intestine. *Locality :* Asia. So far this worm has only been recorded from India, Malay, China and Japan, but further

investigation into cases of Hæmonchosis may indicate a wide distribution.

Morphology.

The worms, preserved in alcohol, were brownish in colour. The specimens examined varied in length from 16 to 23 mm. in the male, and 19 to 26 mm. in the female. The average maximum diameter of the male was .45 mm., and of the female .5 mm. Morishita (1922) mentions males as long as 31 mm. and females of 43 mm.

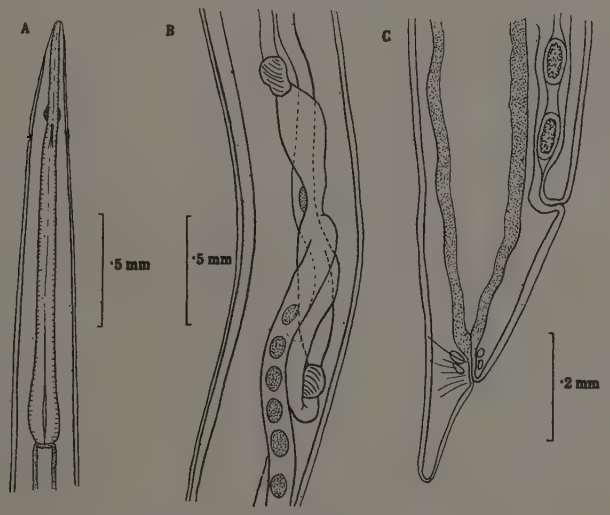

Fig. 7. *Mecistocirrus digitatus*. (A) cephalic end; (B) ovejectors; (C) tail of female.

The cuticle is finely striated transversely. There are, in addition, about 30 longitudiual striations.

The anterior extremity is rounded with six inconspicuous papillæ. The buccal opening is sub-terminal, and opens slightly towards the dorsal side. It is oval in outline, with its long axis dorso-ventral, and is strengthened by small chitinised strips. There is a large buccal tooth present (as in *Hæmonchus*) with muscles attached posteriorily and ventrally. The sharp point of the tooth is dorsal. A dorsal cephalic gland is visible posterior to the base of the tooth.

The œsophagus is long and very slender. It is only slightly swollen posteriorly. The length is about 1.6 to 1.8 mm.

The cervical papillæ are situated at the level of the junction of the anterior and second quarters of the œsophagus, and lie in small depressions in the cuticle.

The nerve ring surrounds the œsophagus about the junction of its anterior and second fifth.

The excretory pore is midway between the nerve ring and cervical papillæ.

The cervical cuticle is only slightly thickened. It becomes very thin anteriorly.

The Female.—The vulva is a prominent transverse slit set in a chitinised area close to the anus, about .55 mm. from the posterior extremity. The body is slightly dilated, just anterior to the vulva, but no trace of the crossed lateral lines, seen by Morishita (1922), could be found. This point requires re-investigation, and is probably erroneous.

The vagina is very long—about 2.9 mm.—and joins the feebly muscular ovejectors centrally. These are equal in size—about .8 mm. each. The inferior ovejector joins the inferior uterus, which almost immediately turns on itself and runs anteriorly—parallel with the superior uterus. The ovaries are spirally coiled round the intestine, as in *Hæmonchus*, and arise in the anterior quarter of the body.

The anus is situated about .2 mm. from the posterior extremity, and joins the intestine by a small rectum.

The posterior extremity narrows rapidly from the anus and is bluntly pointed.

The ova measure .095 to .110 mm. long, and .050 to .055 mm. broad. They are laid in the morula stage.

The Male.—A pair of inconspicuous prebursal papillæ are present just anterior to the commencement of the bursa.

The bursa is completely divided into three lobes. The lateral lobes are spatulate in shape and the tips frequently overlap. It was found to be impossible to completely flatten them out without the aid of dissection needles. The bursa is laminated, and is very elastic. The small lobules noticed by Railliet & Henry (1912) as occurring at the level of the externo-dorsal rays are present only on the folded bursa and disappear on flattening out. The dorsal lobe is small and symmetrical.

The disposition and relative size of the rays are shown in Fig. 8. The latero-ventral and externo-lateral are similar in size, and run together posteriorly for almost their entire length. Their tips are directed away from each other. These two rays are by far the largest in the whole bursa. The ventro-ventral ray is short and slender, and bends outwards, and is widely separated from the latero-ventral ray. The medio-lateral and posterio-lateral rays run close together and terminate about midway

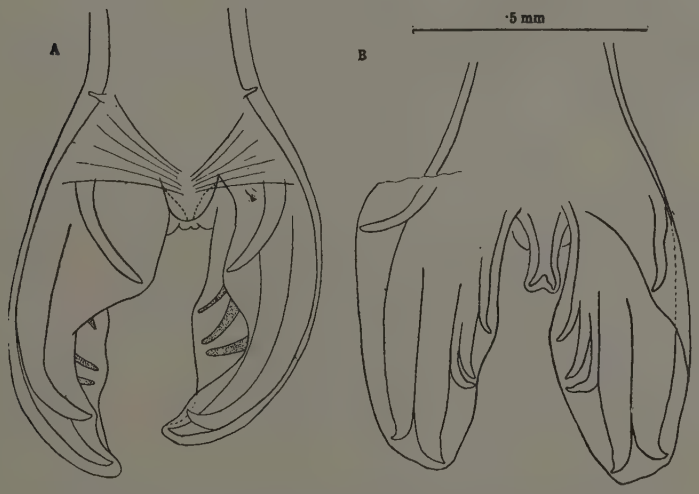

Fig. 8. *Mecistocirrus digitatus*. Bursa. (A) ventral view; (B) compressed (showing all rays).

between the externo-lateral and the externo-dorsal rays. The externo-dorsal ray is also very slender. The dorsal ray is short and bifurcated. Each bifurcation ends in three papillæ—the anterior of which is directed dorsally and the others posteriorly.

The genital cone is supplied with small lateral alae.

No accessory piece could be found.

The spicules are long and slender, and united for almost their entire length. In the specimens examined they were about 5 to 6 mm. long.

Railliet & Henry (1912) record a spicular length of 3.8 to 4.25 mm., while Morishita records the length as 6 to 7 mm. There is, accordingly, considerable variation in the spicular length, but as there is no line of demarkation between these sizes, they cannot be considered as of specific value. The spicular membrane somewhat resembles that found in *Nematodirus*. In the specimens examined the unilateral expansion, shown in Fig. 9B was constant.

Pathogenicity.

This worm is undoubtedly pathological. The somewhat meagre information at our disposal indicates that its affects are very similar to those caused by *Hæmonchus*.

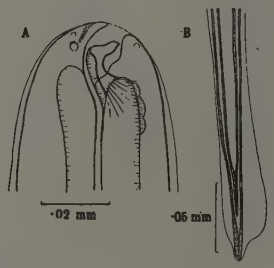

Fig. 9. *Mecistocirrus digitatus*. (A) cephalic end; (B) distal ends of spicules.

Discussion.

There is no doubt that Neveu Lemaire was justified in making this worm the type of a new genus. It appears to be more closely allied to *Hæmonchus* than to any of the existing genera. In naked eye appearance it shows a very great similarity to this worm, and it has probably been mistaken for it in the past.

(4) MOLINEUS FELINEUS. Gen. et Sp. nov.

Host: *Felis yaguarundi.* *Habitat:* Small intestine. *Distribution:* S. America.

The cuticle, except for the swollen cephalic extremity, is striated longitudinally—there being 12 to 14 equidistant lines. Except in the cephalic region only traces of transverse striations can be seen under a high power ($\frac{1}{12}$").

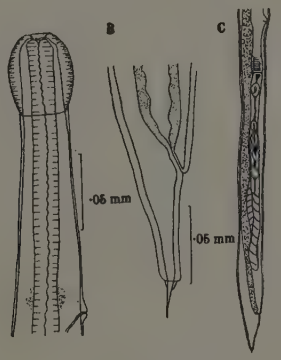

Fig. 10. *Molineus felineus.* (A) cephalic end; (B) female, posterior end (C) female, vulva and uterus.

General.—These are very small slender forms. The male is about 4.75 mm. and the female 5.25 mm. long. Both sexes are about 1 mm. in diameter.

The cephalic cuticle is swollen and conspicuously striated transversely. The swelling completely surrounds the body, but tends to be unilateral. It is about .05 mm. in diameter, and is separated from the rest of the body by a distinct line. There is a small mouth cavity, formed by the inflated cuticle, and this communicates directly with the œsophagus.

No buccal papillæ could be observed.

The œsophagus is straight, slender and tapers anteriorly. There is no distinct bulb. It is about .26 mm. long and 0.03 mm. in maximum diameter.

The Female.—The vulva is a transverse slit, situated about 1.1 mm. from the posterior end. The ovejectors, uteri and ovaries are typical.

The anus is situated about .07 mm. from the posterior extremity, and joins the intestine by a short rectum.

The posterior extremity is bluntly rounded. From it projects a terminal spine (.03 mm. long), formed from the body substance and supported at its base by a cuticular collar.

The nerve ring is situated about midway down the œsophagus.

The excretory pore is just posterior to the nerve ring, and opens on a small protuberance.

Cervical papillæ are absent.

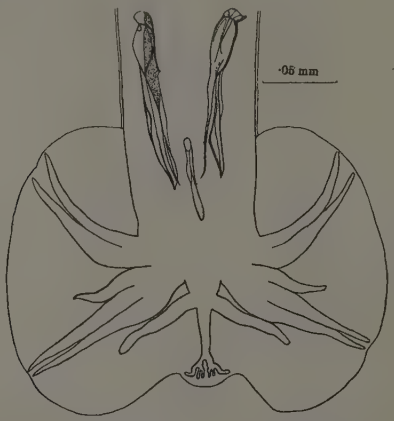

Fig. 11. *Molineus felineus*. Bursa, ventral view.

The ova are oval, thin shelled and about .060 mm. long by .040 broad. They are embryonated when laid.

The Male.—Prebursal papillæ are absent.

The bursa is not distinctly divided into lobes. It is not laminated, but the central portion is covered with small spines. The disposition of the rays is shown in Figs. 11 and 12. The ventral rays are long and parallel, but separated slightly in their distal half. They are directed ventrally and reach the edge of the bursa. The lateral rays, which are also close together and parallel, arise in a common trunk. The externo-lateral ray is only half the length of the other lateral rays and does not

reach the edge of the bursa. It is in apposition with the medio-lateral for about half its length, but its terminal portion is directed ventrally. The medio- and posterio- lateral rays are long and slender, about equal in size and reach the bursal edge. They are directed slightly dorsally. The dorsal ray gives off the externo-dorsals a short distance down its main stem. The externo-dorsal runs parallel with and close to the posterio-lateral, but terminates about half-way down the latter. Its terminal portion is directed slightly dorsally. The dorsal ray splits near its termination into two rays, each of which in turn gives off three digitations—the lateral being much the largest.

The spicules are about .12 mm. long, and are curved slightly ventrally. The double points are directed posteriorly. The posterior point of each

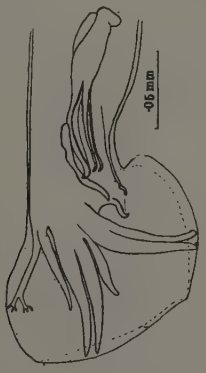

Fig. 12. *Molineus felineus*. Bursa, lateral view.

spicule is much the larger, and seems to be formed of two smaller points fused together. The cephalic end of the spicules is broad and cupshaped.

The accessory piece, .06 mm. long, is an elongated oval in shape, and is flexed ventrally, towards the posterior end.

Pathogenicity.

Unknown. The present specimens were found in association with numerous examples of *Echinococcus*, and of *Ancylostoma pleuridentatum*. The intestine was thickened and slightly inflamed, but these symptoms were probably caused by the other parasites.

Discussion.

This worm shows affinities to a number of the Trichostrongylidæ—particularly *Oswaldocruzia* Travassos, *Hyostrongylus* Hall, *Ostertagia* Ransom, and *Trichohelix* Ortlepp—but shows considerable differences from all of them. It differs from *Oswaldocruzia* in the presence of an accessory piece, in the shape of the spicules, and in the disposition and length of the externo-lateral ray: from *Hyostrongylus* in the disposition and length of the externo-lateral rays and absence of lateral branches to the dorsal ray and of prebursal papillæ: from *Ostertagia* in the absence of an accessory bursal membrane: and from *Trichohelix* in the absence of the cuticular body swelling and in the shape of the spicules and externo-lateral and externo-dorsal rays. These differences seem so considerable that it is proposed to designate this parasite as type of a new genus—*Molineus*—in honour of Molin. This genus differs from all other members of the Trichostrongylidæ, especially by the disposition and size of the externo-lateral ray.

As this is the first trichostrongyle worm found in the Felidæ, the specific name *felineus* is proposed for it. As is the case with many feline parasites, this species is probably not restricted to *Felis yaguarundi*, and search should be made for it in the domestic and other cats in South America.

(5) Molineus torulosus (Molin, 1861).

Syn.:—*Strongylus torulosus* Molin, 1861.
Oswaldocruzia wisei Philpot, 1922.
Trichostrongylus (*s.l.*) *torulosus* Trav., 1922.

Hosts: *Cebus capucinus*. (Recorded by Molin) *Saimiris sciurea*. This species has also been found by the author in *Cebus fatuellus*. *Habitat:* Small intestine. *Distribution:* South America.

A number of specimens of a genus of Trichostrongyle worms have been recovered from the small intestine of squirrel monkeys (*Saimiris sciurea*) from Guiana. They show considerable resemblance to *Oswaldocruzia wisei* Philpot, but differed from that species in the possession of a distinct accessory piece. At Professor Leiper's suggestion an examination was made of the type specimens of *O. wisei*, and it was found that under a $\frac{1}{12}$" objective an accessory piece was present, though extremely difficult to see. In the later examples found by the writer, the accessory piece is easily seen under a medium power. In the new specimens, also, the

externo-lateral ray was shorter than those figured for *O. wisei*. The re-examination of the type material showed that this was also the case in *O. wisei*, but that owing to the folded condition of the bursa, this had not been observed. The bursa and cephalic extremity of the parasite

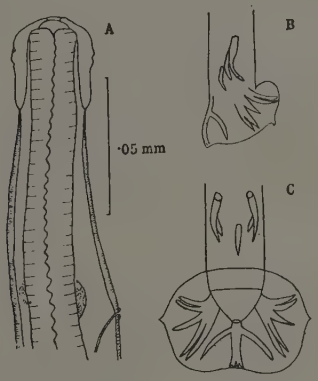

Fig. 13. *Molineus torulosus*. (A) cephalic end; (B) bursa, lateral view; (C) ventral view.

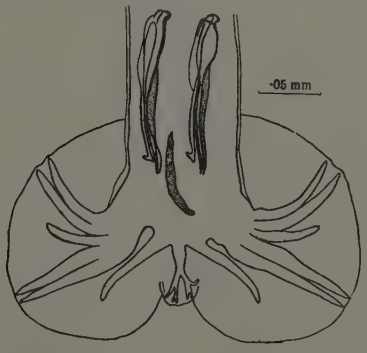

Fig. 14. *Molineus torulosus*. Bursa, ventral view.

are re-figured. (Figs. 13-15.) The peculiar contour of the cephalic swelling is constant.

Molin, in 1861, described from *Cebus capucinus*, from Brazil, a Trichostrongyle worm, which he called *Strongylus torulosus*. In this species the female was 9 mm. long, while the male was 7 mm. Body threadlike

and extremity gradually attenuated to a trunk-like point. Head constricted at base. Mouth terminal, orbiculate and ample with naked borders. Female with vulva in posterior of body far from anus. Uteri double. Caudal extremity conical and needle-like. Anus near caudal extremity. Male with caudal bursa entire. Dorsal ray bifurcated. Ventral rays separated. Spicules simple, short and curved with proximal extremity large and round, and distal extremity pointed. Accessory piece simple, short; base dilated and rounded, apex sharp.

The similarity of Molin's description and diagrammatic figures with that of *O. wisei*, together with the relationship of the hosts and their geographical distribution, lead one to the conclusion that *O. wisei* is a synonym of *S. torulosus*. But the additional facts put forward above

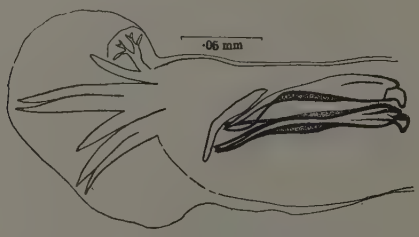

Fig. 15. *Molineus torulosus*. Bursa, lateral view.

show that this worm should *not* be placed in the genus *Oswaldocruzia*. It differs from the type of this genus in the following features:—

	Oswaldocruzia subauricularis.	*S. torulosus*.
i.	Spicules multipointed and complicated.	Spicules with 3 points and comparatively simple.
ii.	E.L. ray approx. same size as M.L. and P.L.	E.L. about half-size M.L. and P.L.
iii.	E.D. little shorter than P.L.	E.D. about $\frac{1}{2}$-size P.L.
iv.	No accessory piece.	Distinct accessory piece.
v.	In reptiles and amphibians.	In mammals.

The name *Oswaldocruzia torulosa* must accordingly be rejected.

Strongylus torulosus shows the greatest affinity to *Molineus felineus*, described in this paper. It differs from it in the following particulars :—

	M. felineus.	*S. torulosus.*
i.	Cervical cuticle with smooth contour.	With notched contour.
ii.	E.L. ray separated from M.L. only at tip.	Separated for entire length.
iii.	Spicules with sharp points only.	Spicules with characteristic hammer-shaped branch.

These points seem to be only of specific importance and, accordingly, this species should be included in the genus *Molineus* with the name *Molineus torulosus* (Molin, 1861).

(6) Viannaia saimiris. Sp. nov.

Host : *Saimiris sciurea.* *Habitat :* Embedded in mucus of small intestine and resembling petechial hæmorrhages. *Distribution :* South America.

Morphology.

The colour, bright red when alive, becomes brown on fixing in alcohol. The cuticle is transversely striated. The worms are always found coiled in a permanent spiral of two to three turns. They do not uncoil on fixing. The male is 3 to 6 mm. long, and the female is 4 to 7 mm. Both sexes are about 0.15 mm. broad.

The cephalic cuticle is swollen and unstriated. This swelling extends for about .075 mm. from the extremity. At this point the body is expanded to meet the in-turning cuticle. This expansion may be homologous with the cervical papillæ, which are otherwise absent.

The mouth is simple, and the swollen cuticle forms a cavity into which the œsophagus opens.

The œsophagus is about .325 mm. long and .02 mm. broad.

The excretory pore is situated about .25 mm. from the extremity.

The nerve ring could not be distinguished.

The Female.—The vulva is an inconspicuous slit situated about .26 mm. from the posterior extremity.

The single ovejector is very muscular, and leads into a single uterus and ovary.

The anus is about .085 mm. distant from the posterior extremity, and joins the intestine by a short rectum about .06 mm. long.

The posterior extremity is sharply pointed.

The ova are about .060 mm. long and .035 mm. broad.

The Male.—The bursa is ample and is indistinctly divided into three lobes. There are no prebursal papillæ.

The ventral rays rise together, but proceed at right angles to each other. The ventro-ventral is shorter and thinner than the latero-ventral, which terminates in a projection on the edge of the bursa. The lateral

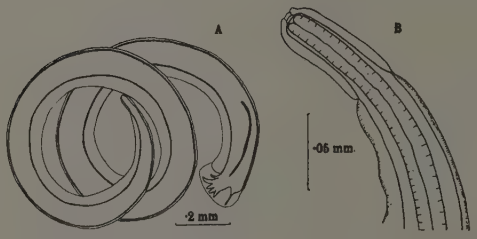

Fig. 16. *Viannaia siamiris.* (A) entire male; (B) cephalic end.

rays arise on a common stem, but diverge widely. The externo- and medio- lateral diverge about half-way down their length, but the posterio-lateral diverges from its origin. The dorsal trunk gives off the externo-dorsal rays about half-way down its length. The externo-dorsal is long, thin and narrows just before its termination into a finger-like process. The dorsal ray bifurcates in its first quarter. Each bifurcation terminates in two digitations. All the rays approach the edge of the bursa.

The spicules are .25 mm. long, simple and in close apposition for most of their length.

There is no accessory piece.

Pathogenicity.

Unknown.

Discussion.

The presence of only one ovary shows at once that this nematode belongs to the sub-family *Heligmosominæ* Travassos. Although this sub-family is a very compact and obvious one, much confusion still exists among its genera, in spite of the work of Hall and Travassos, mainly on account of the incomplete descriptions in existence. The type species of the type genus is very inadequately described, and has never even

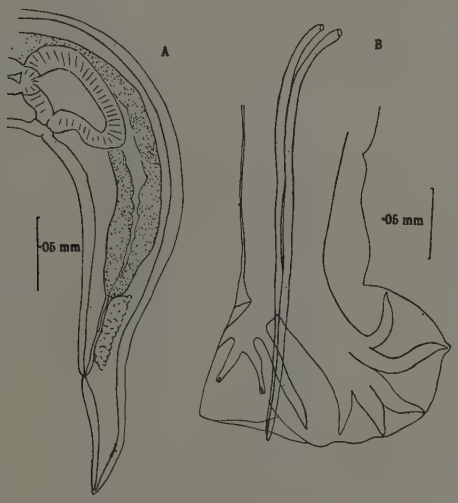

Fig. 17. *Viannaia siamiris.* (A) posterior end of female; (B) Bursa, dorso-lateral view.

been figured. Travassos (1921) considers that the disposition of a body " strongly rolled in a spiral in a definite manner is a very good characteristic." Hall (1916) also places some stress on this point. This feature would divide the *Heligmosominæ* into two groups—*Heligmosomum* R. & H. and *Heligmostrongylus* Travassos, which are not rolled in a spiral; and *Viannaia* Travassos, *Viannella* Travassos, and *Heligmosomoides* Hall, which are rolled spirally.

In *Heligmosomoides* the vulva is anterior, while in *Viannella*, the ventral rays, and also the M. L. & P.L. rays, are united in their basal two-

thirds. *Viannaia*, as at present accepted, would be the genus for the present species. It would seem, however, that the genus requires splitting. This species corresponds to none of the already described species of *Viannaia*, and the specific name of *Viannaia saimiris* sp. nov. is proposed for it.

General Remarks on Generic Diagnosis.

In this paper it has been found necessary to create two new genera. The omission of a formal generic diagnosis is an intentional one. A genus is simply a collection of species which are considered by an author to resemble closely a type species. The delimitation of certain specified characters as being of generic value and others of only specific value has led to endless confusion—and is after all merely an expression of opinion. At the same time, it is not denied that the drawing of attention to what an author considers are the more salient points in a genus is of considerable value. As, however, the classification of all the parasitic worms is in such a condition of flux in our present state of knowledge, it is considered that the creation of artificial generic diagnosis is not only fruitless, but tends to spoil the elasticity of a true evolutionary classification. It is not suggested that short descriptions of the higher groups should be abolished. On the contrary, they are of considerable value, and have more permanence than the genus—even admitting that many of our families and sub-families are purely artificial and require revision.

KEY TO THE GENERA OF THE FAMILY *Trichostrongylidæ* LEIPER.

A. Sub-family *Trichostrongylinæ* Leiper. (Double genital apparatus in female) 1

1. Head with umbrella-shaped membrane ... HISTIOSTRONGYLUS Molin
   Head without umbrella-shaped membrane 2

2. Spicules short with ridges and projections 3
   Spicules long and filiform 12

3. Accessory piece present 4
   Accessory piece absent 10

4. Acc. piece ring-shaped; prebursal papillæ absent ORNITHOSTRONGYLUS Trav.
   Acc. piece wedge shaped; prebursal papillæ present or absent ... 5

5. Dorsal lobe of bursa asymmetrical ... ... HÆMONCHUS Cobb.
   Dorsal lobe symmetrical 6

6. V.V. ray separated from and smaller than L.V.; prebursal pap. absent ... ... TRICHOSTRONGYLUS Looss.
   V.V. ray close to and about same size as L.V.; prebursal pap. present or absent 7

7. Acc. bursal membrane present ... ... OSTERTAGIA Ransom
   Acc. bursal membrane absent 8

8. Prebursal papillæ present; no cephalic dilation HYOSTRONGYLUS Hall
   Prebursal papillæ absent; cep. dilation present 9

9. E.L. same size as other lateral rays ... ... TRICHOHELIX Ortlepp
   E.L. half-size of other lateral rays ... ... MOLINEUS Cameron

10. Prebursal papillæ conspicuous ... ... TRAVASSOSIUS Khalil
    Prebursal papillæ absent 11

11. Dorsal ray lyre shaped; spicules with simple points COOPERIA Ransom
    Dorsal ray like "capital of columns"; sp. with multiple points OSWALDOCRUZIA Trav.

12. Spicules with multiple points ... ... GRAPHIDIUM Railliet & Henry
    Spicules with simple points 13

13 Vulva close to anus; Vagina long; uteri parl. MECISTOCIRRUS Nev. Lem.
   Vulva remote from anus; Vagina short; uteri divergent 14

14. Ventral rays same size and parallel ... ... NEMATODIRUS Ransom
    V.V. much shorter than L.V. and divergent ... GRAPHIDIOIDES Cameron

B. Sub-fam. *Heligmosominæ* Travassos. (Single genital apparatus in female) 15

15. Body rolled in a perm. spiral 16
    Body not in a perm. spiral 18

16 Vulva near cephalic extremity ... ... HELIGMOSOMOIDES Hall
   Vulva in posterior half of body 17

17 Ventral rays, and also M.L. & P.L. united in basal two-thirds VIANNELLA Trav.
   Ventral rays, and also M.L. & P.L. not united in basal two-thirds VIANNAIA Trav.

18. Dorsal ray, single ... ... HELIGMOSOMUM R. & H.
    Dorsal ray, double ... ... HELIGMOSTRONGYLUS Trav.

NOTE 1.—Of the two remaining genera, males only are known. Travassos (1921) is of the opinion that the first (*Warrenius* Hall) is a species of *Heligmosomum*; and the second (*Citellinema*) a species of *Viannella*.

NOTE 2.—The above table is only intended as a means for identifying the various genera, and not as an attempt to show their relationships.

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Journal of Helminthology, 1923. *Vol.* I., *pp.* 97-98.

A Distomid Larva infesting the Egyptian Mullet.

By Harujiro Kobayashi.

Chosen Government-General Hospital, Keijo.

From the researches of Onchi and Nishio it is known that the encysted larva of *Heterophyes nocens* Onchi et Nishio is found in the Japanese mullet. *H. nocens* is closely allied to *H. heterophyes* v. Siebold, which is found commonly in man, dog and cat in Egypt. It may be assumed that the larva of the Egyptian *Heterophyes* will be found likewise in certain fishes allied to the mullet. On the homeward voyage from my tour in Europe I examined some specimens of mullet in Port Said,* for the purpose of finding the young larva in them, and was fortunate enough to discover encysted larva. I carried back with me some of these fishes fixed by formalin. After returning to Chosen (Korea) I examined the parasite, and found that it certainly belongs to a species of *Heterophyes*. Its morphological description is given in the present short communication.

The young distome encysts in the flesh of the host. It occurs very commonly, the number in one fish often exceeding several hundreds. The cyst is commonly spherical in shape, its diameter being 0.16 to 0.19 mm. The cyst-wall is moderately thick and tough. There are very thin enclosing sacs exterior and interior to the cyst-wall proper.

The distome lies folded up itself in the cyst. When it is taken out from the cyst and is extended completely it measures 0.2 to 0.46 mm. (ordinarily 0.3 mm.) in length. The body is composed of two parts, an anterior flat and ellipsoidal part and a posterior inflated wider part. The breadth of the anterior and the posterior part is 0.07 to 0.11 mm. and 0.092 to 13 mm. respectively.

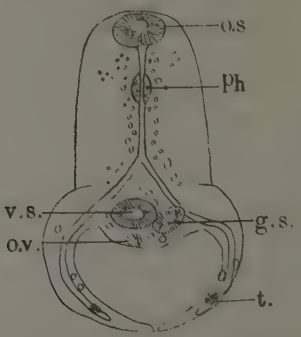
Scale-like cuticular spines are well developed, covering all over the anterior body and anterior part of the posterior body. The parenchyma is grey in colour and contains brown, relatively few, coarse, spherical pigment granules. Numerous gland cells lie in the anterior part of body, and certain ducts from them open at the anterior end, near the ventral surface.

* I cannot say definitely its specific name, but it may be *Mugil cephalus* or an allied species.

Both suckers are well developed. The oral sucker, which is elongated transversely, lies ventrally at the anterior end of the body, the size being 0.024 to 0.028 × 0.032 to 0.04 mm. The ventral sucker lies between the anterior and the posterior body, and is elongated transversely similarly to the oral sucker. In size it is almost the same as the oral sucker. Directly posterior to and on the left of the ventral sucker a genital sucker is present. It is smaller than the ventral sucker, the breadth being 0·024 mm.

The prepharynx, the pharynx, the œsophagus, and the intestine are well differentiated. The œsophagus is long and slender. The intestinal cæca reach near to the posterior end of the body.

The excretory vesicle is V-shaped, lying in the posterior part of the body.



There are rudimentary testes and ovary in this posterior portion. The former are small and ellipsoidal cell-masses, being near the posterior end of each intestine and overlapping it. The ovary lies directly posterior to the ventral sucker.

The presence and the position of the genital sucker and other features show that this young distome belongs to the genus *Heterophyes*. As I had no chance to experiment on animals, its adult form is not yet known. From the morphology and the locality it can be said safely that this is the young stage of a species of *Heterophyes*, one closely allied to *H. heterophyes*. I hope that this will be determined by an investigator who has favourable opportunities to make the necessary experiments.

Journal of Helminthology, 1923. *Vol.* I. *pp.* 99-117.

The Anatomy of *Monodontus trigonocephalus* (Rud.) of Sheep.

By T. W. M. Cameron, M.A., B.Sc., M.R.C.V.S.

Since Looss described in detail the anatomy and histology of the type species of the family *Ancylostomidæ* no attempt has been made to study comparatively any of the other genera of this group.

From its economic importance as a little-known, though frequent, parasite of ruminants and its scientific importance as type species of the second sub-family of the *Ancylostomidæ, Monodontus trigonocephalus* has been selected for description.

The lines laid down by Looss in his classical study have been closely followed. Many points in the two species have been found to be identical, and as no useful object would be served by re-describing these points, differences only have been described in detail while resemblances have been merely noted. In this way it has been possible to greatly shorten the paper without, it is hoped, reducing its value. It is, of course, understood that the following description should be read in conjunction with Looss' work on *Ancylostoma duodenale.*

Nomenclature.

Specific Name.—In 1802, Rudolphi described *Strongylus trigonocephalus* from material labelled as coming from the *dog*. This worm, according to Railliet, is identical with the worm found in sheep, and has never since been reported from the dog ; so that we may assume that the bottle was wrongly labelled. Creplin, in 1829, was the first to describe it from the sheep under the name of *Strongylus cernuus*. In later years it was frequently confused with the worm now known as *Chabertia ovina* (Syn *S. hypostomum* Rud.). Dujardin and Diesing, for example, included both forms in Rudolphi's species. It is now recognised on the authority of Railliet (1900), that *S. cernuus* and *S. trigonocephalus* are synonyms, and consequently, the latter name, having priority, becomes the true specific name.

MONODONTUS TRIGONOCEPHALUS (Rud.) Railliet, 1900.

Synonyms :—

Strongylus trigonocephalus Rud., 1808.
Strongylus cernuus Creplin, 1829.
Sclerostoma hypostomum (Rud.) Duj., 1845 (pp.).
Dochmius hypostomum (Rud.) Dices., 1851 (pp.).
Monodontus Wedlii Molin, 1861.
Dochmius cernuus (Crep.) Railliet, 1868.
Uncinaria cernua (Crep.) Railliet, 1885.
Strongylus (*Monodontus*) *cernuus* (Crep.) Railliet, 1900.
Uncinaria (*Monodontus*) *cernua* (Crep.) Railliet, 1900.
Monodontus trigonocephalus (Rud.) Railliet, 1900.
Bunostomum trigonocephalum (Rud.) Railliet, 1902.
Bunostomum kashinathi Lane, 1917.

Hosts : *Ovis aries* (Sheep), *Capra hircus* (Goat), *Bos taurus* (Ox).

Habitat : Small intestine.

Distribution : Scotland (Cameron), England (Boulenger), India (Lane), Europe (Molin and others), Africa (Gedoelst), America (Ransom).

Generic Name.—In 1861, Molin created his new genus *Monodontus* with two species, *Wedlii* and *semicircularis*. The first-named was from the sheep and is obviously a synonym of *S. trigonocephalus* Rud. No type, however, was mentioned. In 1895, Railliet, speaking of *trigonocephalus*, says : " Molin had made of it, not without some reason, the type of a distinct genus (Monodontus)," (" Molin en avait fait, non sans quelque raison, le type d'un genre à part (Monodontus).") In 1899 Stiles and Hassall, in speaking of a new species of *Uncinaria*, cite as a generic synonym : " 1861 *Monodontus* Molin—Type *M. semicircularis*." In 1905 they explain that this was because Molin had created his genus mainly from his second species. However, under the International Rules of Nomenclature, a type species, once designated, even if designated by a subsequent author, is valid. There is no doubt that Railliet had designated *Wedlii*, now known as *trigonocephalus*, as type of the genus *Monodontus* before Stiles and Hassall, and accordingly it must stand.

In 1902 Railliet changed the name *Monodontus* to *Bunostomum* on the ground that *Monodontus* resembled the previously occupied genera *Monodononta* and *Monodon*. This change is invalid.

In 1905 Railliet split the genus into two new genera, *Bunostomum* (type *trigonocephalum*) and *Eumonodontus* (type *semicircularis*). The genus *Bunostomum* is a synonym of *Monodontus*. The species *semicircularis*, however,

differs from the type of *Monodontus* in the symmetry of the externo-dorsal rays. This is obvious, not only from Molin's figure, but from his description of *Wedlii*, where he points out that the asymmetry of the externo-dorsal ray in that species is characteristic. In his figure of *semicircularis* he draws this ray symmetrically, and makes no mention of any asymmetry in the text. There is no doubt that this asymmetry is a generic characteristic, and accordingly we must admit the genus *Eumonodontus* Railliet (type *E. semicircularis*) as valid.

Technique.

The technique described by Looss in his various works on the *Strongylidæ* was used. The specimens were killed in hot alcohol and glycerine. It was found, however, that Lacto-phenol was a better clearing agent than glycerine. Some specimens kept in this fluid for three years were absolutely unchanged, and the details could be made out with the greatest ease. In a few cases beechwood creosote was useful—as for spicules, bursal muscles, and œsophageal glands. Sections were stained with eosin-hæmatoxylin. Dissections were made with sharpened needles under the binocular microscope.

Material.

All the material used for this study was obtained from sheep killed in Scotland. It was mostly collected at Slateford abattoir, and the writer has to thank Mr. J. Howard Jones, M.R.C.V.S., for the valuable facilities given him for collecting and preserving specimens.

The material for *M. phlebotomus* was obtained partly from Prof. Warrington Yorke through Prof. Leiper. The writer would take this opportunity of expressing his great indebtedness to Prof. J. H. Ashworth and Prof. R. T. Leiper for advice, criticism and laboratory and library facilities offered him in this study.

External Appearance and Shape of the Body.

Length.—Ransom (1911) describes the male as 12 to 17 mm. long and the female as 19 to 26 mm. long. All the specimens examined were within these limits, the maximum observed being 16.5 mm. for the male and 26 mm. for the female. As the great majority of the parasites were between 14.5 and 15.5 mm. in the male and 22 and 24 mm. in the female, the average sizes of 15 mm. and 23 mm. respectively were taken as stan-

dard, and all subsequent measurements refer to worms of these lengths.

Thickness.—The thickness of the male is about .45 to .50 mm., and of the female .48 to .75 mm.

Colour.—The colour of *Monodontus trigonocephalus* is normally a translucent flesh colour, but occasionally dark-brown specimens are obtained, the pigment coming presumably from ingested blood.

Shape.—Apart from their greater length, these worms are similar in shape to *Ancylostoma*. Like *Ancylostoma* also they show the same longitudinal torsion, and, when placed on a slide with the dorsal aspect of the cephalic opening facing upwards the posterior extremity is displaced laterally.

Papillæ.—The cervical papillæ are similar in shape to those present in *Ancylostoma*, and lie laterally just anterior to the middle of the œsophagus. The prebursal papillæ in the male and caudal papillæ in the female are present, but in neither case do they reach the surface of the cuticle.

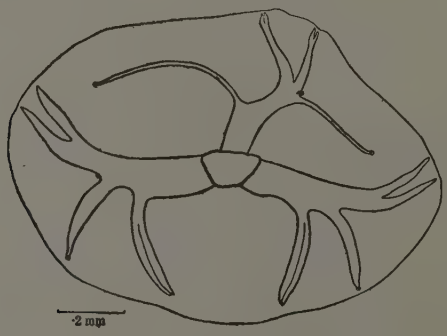


Fig. 1. *Bursa detached and spread out.*

Posterior End of Body.—In the female the slight dorso-ventral compression posterior to the anus observed by Looss in *Ancylostoma* is also evident. The termination ends in a sharp point, but the body substance never projects *through* the skin, although occasionally projections *into* the skin may be observed. The truncated appearance in Ransom's figure is due to shrinkage, and is not so obvious in the unfixed specimen.

In the male there is a tendency, less marked than in *Ancylostoma*, to become quadrangular. A large genital cone is present.

The *bursa* is closed on all sides, and the dorsal lobe is only slightly developed. The lateral lobes are continuous ventrally. The dorsal lobe is always asymmetrical and on the right of the middle line. This is shown in Fig. 1.

Rays.—In general the bursal rays follow the plan seen in *Ancylostoma.* The dorsal ray arises in a smallish dorsal trunk. Near its termination (at a varying distance) this ray splits into two diverging branches—both of which are directed towards the right lateral lobe. Each of these branches ends in a double or triple point. These terminal digitations vary both in size and number, but there is never found an arrangement similar to that in *Ancylostoma.* Like that species, however, each branch terminates in only one small papilla on the inner surface of the bursa.

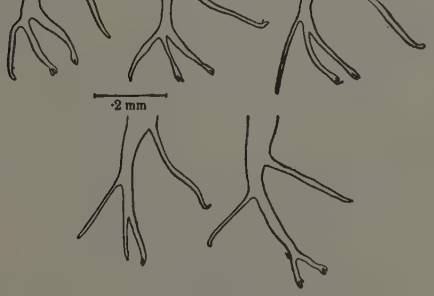


Fig. 2. *Variations in the dorsal ray.*

The externo-dorsal rays always rise asymmetrically. In several hundreds examined the right ray has always been given off nearer the base of the dorsal ray. The left externo-dorsal ray is given off at a varying point between the right and the proximal portion of the left diverging branch of the dorsal ray (Fig. 2). In some cases it is given off by this branch, in other cases in common with it, in most cases it is given off by the dorsal ray a short distance anterior of the diverging branches, but in a few examples it arises just posterior of the right externo-dorsal. It is always asymmetrical, but its variable point of origin indicates a degree of plasticity which probably can be associated with recent evolution. Too

much stress should not be put on this point in classification. The two externo-dorsal rays are unequal in length, but always terminate about the same level in small papillæ on the external surface of the bursa. The ventral rays are the first to branch off from the main stem of the lateral trunk. They are slender rays divided only in their distal two-thirds, but both continuing to run close together and terminating on the internal surface of the bursa. The next ray to be given off is the externo-lateral. This is a stout ray diverging from the other laterals and curving in a ventral direction. It terminates in a small papilla on the exterior of the bursa. The medio-lateral and posterio-lateral rays diverge slightly from each other, but, as both are curved in a dorsal direction, this divergence is not so evident as their divergence from the externo-lateral. These two rays terminate in small papillæ on the internal surface of the bursa.

The *skin* consists of the same two layers as noted by Looss, and both layers are striated. The average thickness is about .04 mm., but it becomes very quickly thinner anterior to the cervical papillæ. Over the buccal capsule it is about .008 mm. in thickness. The whole body is finely striated transversely. Unlike *Ancylostoma*, these striations continue on to the cephalic cuticle, where, however, they become very faint and can only be seen under an oil immersion lens. The post-anal region of the female is striated except for a very small area at the tip. The bursa is formed as in *Ancylostoma*, and is finely, though irregularly, transversely striated.

The " chitinous rod " of Looss is present and terminates posteriorly as in *Ancylostoma*. Its anterior limits could not be found.

The *Sub-cuticle* and *Lateral Bands* are disposed exactly as in *Ancylostoma*.

The *Cephalic Glands* are by no means so conspicuous in this species, even when alive, as in *Ancylostoma*, but otherwise they are identical. They are best seen in specimens cleared in Lacto-phenol.

Four dorsal pairs of cephalic *muscles* are seen in cleared specimens. A fifth can be seen in transverse sections. The ventral arrangement is similar. A dorsal and a ventral pair of cephalo-œsophageal muscles rise from the œsophagus about the region of the nerve commissure and run anteriorly. Each muscle appears to be double.

The *body cavity* contains an albuminous fluid. It is sometimes pink in

colour, presumably from the intestinal contents. Strands of a fibrinous substance of unknown significance are also found.

The Digestive Tract.

The *buccal capsule* consists of a single piece of " chitin " (it should be noted that this substance has not the same composition as the " chitin " of the arthropods, as when treated with caustic potash it dissolves). The form of the mouth capsule is slightly variable, the more usual shape being illustrated in Fig. 3, but longer or shorter specimens are seen. It is seen to resemble an inverted cone, the base of which is oval with a maximum dorso-ventral diameter. In an average specimen the height of this cone is .1 mm., but variations are frequent, and may give an elongated or a rounded appearance to the capsule when viewed in profile. The chitinous

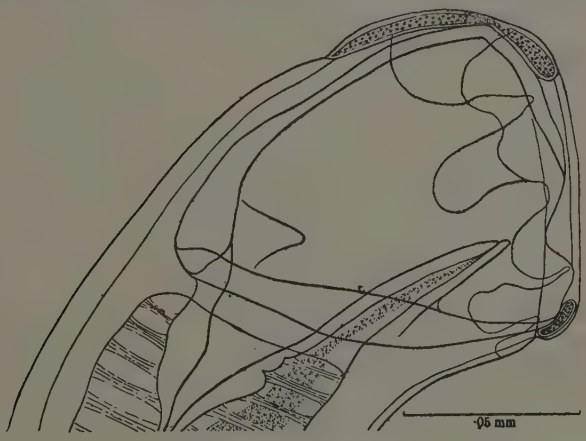


Fig. 3. *Lateral view of Buccal capsule.*

wall is not of a uniform thickness, the maximum thickness being at the base of the capsule. The wall becomes thinner progressively forwards. From the chitin in the mouth opening two ventral " dental plates " project into the actual opening. These have smooth, sharp, free-cutting edges. Similar but smaller and non-cutting projections are apparent at the dorsal edge of the mouth opening. The dental plates have no ribs and no teeth, and are absolutely smooth. They accordingly differ from *Ancylostoma duodenale* in a number of very important points. They project into the mouth opening with sharp cutting edges, they have no ridges,

and they have no teeth. They must be looked upon as having evolved through rather different lines from *Ancylostoma*. Both may be regarded as descending from a common ancestor possessing teethless non-projecting and non-cutting plates. In the one sub-family these have evolved projecting teeth while remaining themselves non-projecting. In the other sub-family they have become projecting, and instead of secondary teeth have become themselves cutting and undivided. The genus *Agriostomum*, when better known, may represent a third, but parallel evolutionary series.

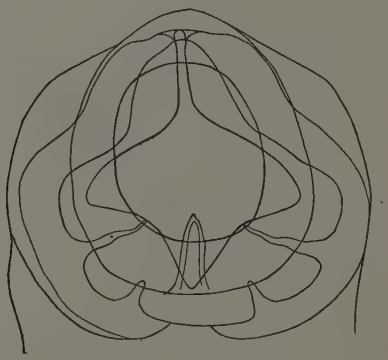


Fig. 4. *Dorsal view of Buccal Capsule.*

From the inner lateral walls of the capsule, near the opening into the œsophagus, project two small cutting lancets. These are much more pyramidal in shape than in *Ancylostoma*, but variations are frequent. They may be bifid or even square. In some specimens a smaller pair of sub-ventral lancets are found on the lateral walls of the capsule. Their dispositions in two specimens dissected to show this point are figured (Fig. 6). These lateral lancets vary in size, and the specimens in which they are found are absolutely typical. This shows conclusively that a new species cannot be formed on this point. In *M. phlebotomus* they are present also, but are much larger. In that species, however, other more reliable differences are found.

The anterior edge of the buccal capsule is formed not of chitin but of skin, and is oval in outline, the dorso-ventral diameter being larger. The

sinuous outline of the chitinous framework can be seen through this skin. As already noted, this projects in four places. The cuticle surrounds the mouth, and is thickened to form a pad which becomes filled with a granular substance between the two cuticular layers, the inner of which adheres closely to the chitinous framework. A cephalic-œsophageal ligament connects the mouth capsule to the œsophagus.

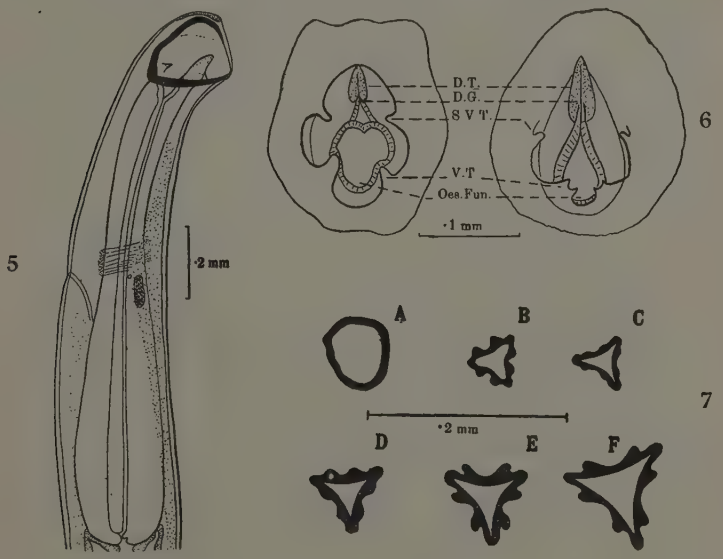


Fig. 5. *Lateral view of cephalic end.*
Fig. 6. *Sections of Buccal Capsule to show:* S.V.T. *subventral teeth;* D.T., *dorsal tooth;* D.G., *dorsal gutter* V.T., *ventral teeth.*
Fig. 7. *Transverse sections of the cuticular lining of the œsophagus at various levels.*

On the posterio-dorsal aspect of the buccal capsule is the opening of the œsophageal funnel. At the dorsal edge of this the opening of the dorsal œsophageal gland is found. The duct, instead of continuing parallel to the buccal wall as in *Ancylostoma*, projects into the interior on a papilla—the so-called " dorsal tooth." The duct opens near the tip of this tooth on its *ventral* aspect. The significance of this arragement is not understood. The size of this tooth and the angle at which it rises is subjected to slight variations. Ransom (1911) has noted that the length of its dorsal edge

is always greater than the distance between its tip and the mouth opening. Although the size of the tooth varied, this relationship was found to remain true.

The *Œsophagus*.—The size and shape of this organ are shown in Fig. 5. The length is about 1.3 mm., and the maximum breadth is .25 mm. The œsophageal funnel is a single piece of chitin. Its buccal margin is more or less round (Fig. 7 A), but is somewhat variable in shape, and projections immediately posterior to the lancets, are occasionally found directed into its lumen. The œsophageal margin is triradiate.

The chitinous lining (Fig. 7) differs in shape from *A. duodenale*. Its lumen is similar, but the exterial chitinous thickenings differ.

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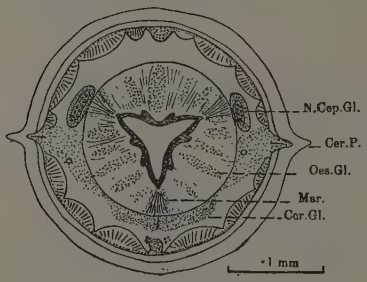

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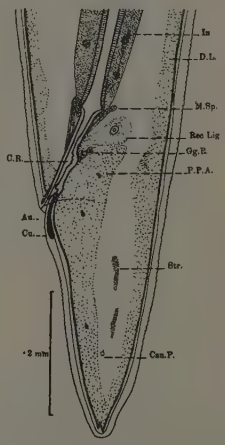


Fig. 8. *Transverse section at level of cervical papillæ* (Cer.P.). *Nucleus of cephalic gland* (N.Cep.Gl.). *Marginal fibres* (Mar.). *Cervical Gland* (Cer.Gl.). *Œsophageal Gland* (Oes.Gl.).

Fig. 9. *Sagittal section of posterior end of female: Intestine* (In.). *Dorsal Line* (D.L.). *Sphincter Muscle* (M.Sp.). *Rectal Ligament* (Rec.Lig.). *Pulvillus postanalis* (P.P.A.). *Rectal Ganglia* (Gg.R.). *Anus* (An.). *Cuticle* (Cu.). *Protoplasmic strands* (Str.). *Rectal Lumen* (C.R.).

Three rudimentary œsophageal valves are found posteriorly. The musculature is of two kinds—marginal and ordinary.

Three longitudinal nerve fibres are found in the substance of the œsophagus. There are three œsophageal glands—a dorsal and two latero-ventral. The apertures of the latero-ventral glands occur in the lining of the œsophagus about the level of the nerve ring. That of the dorsal gland is on the dorsal "tooth." Each gland consists of a median and two

lateral trunks, the latter giving off numerous " internal " ramifications. The nuclei lie in the posterior valvular region of the œsophagus.

The *Intestine*. Like *Ancylostoma*, the intestine is a single organ composed of an inner and outer layer of cells, some of the inner layer being pigmented.

In both sexes the intestine terminates in a short rectum surrounded by a voluminous rectal ligament.

The intestinal contents are generally of a light pinkish colour, but occasionally are dark brown.

The *Rectum* is a chitinous tube about .2 mm. long. This tube has a slight dilation on its dorsal wall similar to that in *A. duodenale*. In addition, in the posterior portion there may be an inconstant small dorsal dilation. The posterior chitinous plate is more posterior than in *Ancylostoma*, and is continued into the post-anal cuticle. The ventral portion is also larger, although smaller than the dorsal.

The anterior portion of the rectum and its remaining structures are as in *Ancylostoma*.

The *Excretory Apparatus and the Cervical Glands*.—The excretory pore lies on the ventral side slightly behind the nerve ring. The excretory apparatus and the cervical glands are identical with *Ancylostoma*.

The *Genital Organs*.—The *male* genital organs follow the same plan as in *Ancylostoma*, and only differ from it in smaller details. The testis is about $1\frac{1}{4}$ to $1\frac{1}{2}$ times as long as the whole body length. The testicular coils never surround the intestinal tube, but zig-zag backwards and forwards. The seminal vesicle is about 1 mm. long, and joins the cement gland by a short tube, *i.e.*, as in *Ancylostoma*, not as in *Necator*. The cement gland is about 3.3 mm. long.

The *spicules* are .65 mm. long and are equal in size. They differ considerably from those of *A. duodenale*. The free end of each terminates in a spatulate point (Fig. 10). This terminal portion consists of almost transparent chitin supported by two—sometimes three—dark ridges which, under a low power, gives the point a bifid (or even trifid) appearance. The point is easily broken by pressure. The spicules are not straight, but form a double S in outline. They lie close together at their distal ends, which are both turned to the same side, either right or left, but are usually slightly separated proximally. They normally do not overlap,

but after the worm has been " rolled " several times an overlap may be found. The proximal end of the spicules is a long open oval into which the spicular pulp passes.

In cross-section the spicules are round. Transverse ridges are absent, but sculpturings are present.

Each spicule is enclosed in a spicular sheath. This is attached to the rim of the oval referred to above. Near the distal end of the spicules it

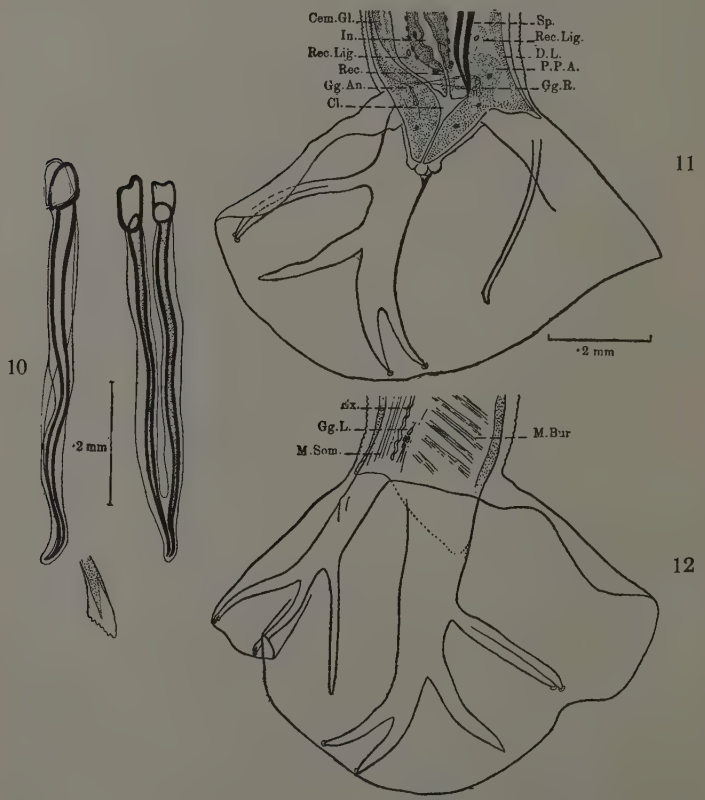


Fig. 10. *Spicules: lateral and dorsal views, and terminal of a spicule enlarged.*
Figs. 11, 12. *Bursa: lateral halves after splitting almost sagittally.*

unites with the sheath of the other spicule and continues thus, terminating blindly just beyond the free end. This sheath is conspicuously transversely striated. When the spicules are extruded this sheath accompanies them. The gubernaculum, referred to by Looss as being embedded in the dorsal wall of the spicule canal, is absent in *Monodontus*.

The *genital cone* in *Monodontus* is a conspicuous structure, and projects considerably above the floor of the bursa. The cloacal opening is subterminal. The apex of the cone is ornamented with cuticular swellings. The remaining portions of the male genital apparatus are shown in Figs. 11 and 12.

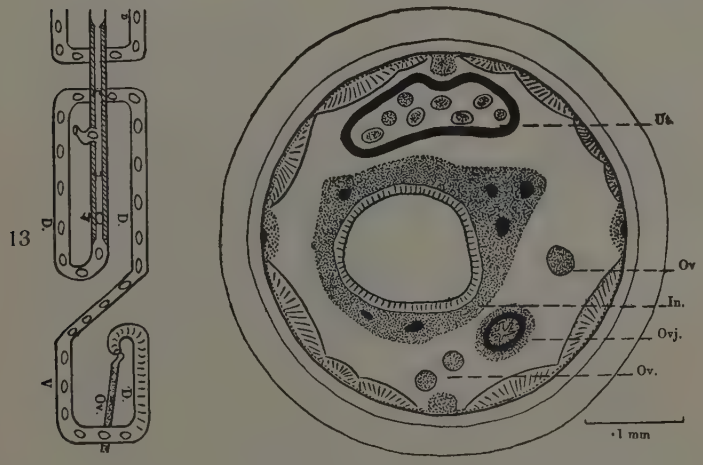
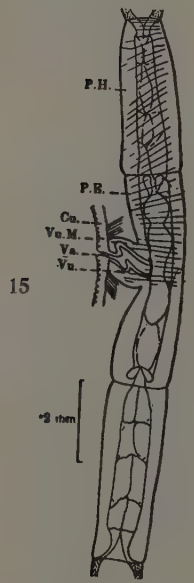


Fig. 13. *Diagram of one uterus.*
Fig. 14. *Transverse section of female just cephalad of vulva.*

The *female* genital organs consist of the same elements as in *Ancylostoma*. Their general arrangements and sizes, however, differ somewhat. The ovaries are disposed in a similar manner, but have few coils in the region of the vulva.

The uteri both run a similar course, and only one will be described. The ovary passes by a very short oviduct—little narrower than itself—into the terminal portion of the uterus, which is modified to form a

receptacle seminalis. This lies dorsally, and runs in a direction away from the vulva. It passes insensibly into the functional uterus containing fertilised ova. The tube turns through a right angle, and running ventrally for some distance, passes obliquely to the dorsal surface (Fig. 13). It runs in a straight line to about the level of the vulva, turns sharply on itself, and, still dorsal, runs parallel to the first portion for some distance.



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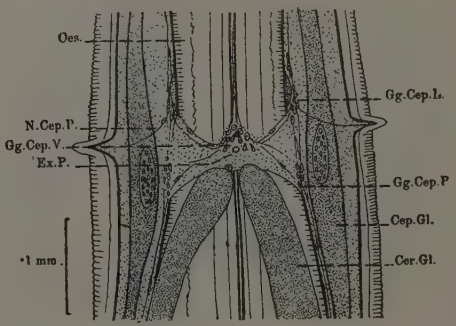

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Fig. 15. *Ovejectors.*
Fig. 16. *Section of body in region of nerve commissure: Nerve to cervical papillæ* (N.Cep.P.). *Ventral, Lateral, Posterior Cephalic Ganglia* (Gg.Cep.V., Gg.Cep.L., Gg.Cep.P.).

Again passing ventrally, it turns through a right angle, and continues towards the vulva. The terminal portion is modified to form an ovejector. Like *Ancylostoma*, this ovejector may be divided into two portions—a relatively long *pars haustrix* and a shorter *pars ejectrix*. In internal structure also it is similar, but externally it is a smooth tube, the bulgings seen in *Ancylostoma* being absent. The vulva is a broad lateral slit without

lips. It leads into a short S-shaped vagina, which is, however, somewhat larger than in *Ancylostoma*. A nerve encircles the junction of vagina and ovejectors.

The course of the uterus is best studied in fresh specimens. In these the gap between the two uteri—only crossed by the intestine, ovejector and two strands of ovary—is very conspicuous.

The *nerve ring* is situated on a fibrous commissure just anterior to the excretory pore. This ring has a decided dorso-ventral tilt—the dorsal side being the higher. Associated with it may be seen the five ganglia found by Looss—the ventral and the two sets of lateral. A large ventral and two large lateral nerves, and a small dorsal nerve similar to *Ancylostoma*, were seen, but the finer nerves seen by Looss could not be made out with certainty. Large anal ganglia are present in both sexes, and the nerves running into the bursal rays in the male are similar to those in *Ancylostoma*.

Bunostomum kashinathi Lane, 1917.

This species has been described by Lane as occurring in the goat in India. He differentiates it from the type species on a number of very small points as follows :—

	B. trigonocephalum.	*B. kashinathi.*
(*a*)	Mouth cavity longer than broad.	Mouth cavity generally globular.
(*b*)	Dorsal edge of dorsal tooth almost parallel to cephalad part of dorsal boundary of the oval capsule.	Dorsal edge set at an acute angle.
(*c*)	Ventrad edge of dorsal tooth in same line as fundus of oval capsule.	Ventrad edge makes an obtuse angle with fundus.
(*d*)	Spicules lyrate when veiwed from dorsad or venter. At a point about .35 mm. from cephalad end the right spicule passes ventred of left. Caudad of this "daylight" may be seen between the spicules. Striation of cuticular expansions but little evident.	Spicules nearly straight from side, but diverge slightly from bases (when viewed from dorsad or venter) and again approach. They cross at a point .6 mm. from cephalad end and only a small patch of daylight is seen. Striations evident.
(*e*)	Rays of bursa rather long, slender with smooth outlines.	Rays rather short and stout, and tend to have rugged outlines.
(*f*)	Female tail .25 to .33 mm. long and relatively short and wide. Post-anal prominence is marked.	Female tail .375 to .4 mm. long and relatively long and thin. Post-anal prominence is slight.
(*g*)	In Sheep.	In Goat.

When a large series of specimens are examined, it is found that Lane's characters (*a*), (*b*), and (*c*) disappear. There are numerous small variations in the shape of the buccal capsule and in the shape and angle of the dorsal tooth. These variations grade into each other and are not constant. It is impossible to recognise these small variations as having a specific value.

The spicules of *trigonocephalum* do *not* normally cross each other, and it is only after manipulation under a coverslip that they can be made to do so. They are generally much less lyrate than figured by Lane. The cuticular expansions of that author are in reality envelopes, and in well-preserved specimens are conspicuously striated. The appearance of the rays also is not a specific character as slight variations occur and ruggedness is probably due to unsatisfactory preservation.

Looss (1905, p. 33) has shown that the length of the female tail is useless as a specific character. The post-anal prominence is prominent only in contracted specimens. The type species occurs in Scotland in both sheep and goats, and no differences could be found between specimens from different hosts. It is evident, therefore, that on the examination of a large series of well-preserved specimens, the difference between *kashinathi* and *trigonocephalum* disappear. Accordingly, *B. kashinathi* Lane cannot be accepted as a valid species, and must be cited as a synonym of *M. trigonocephalus*.

Monodontus phlebotomus Railliet, 1900.

Synonyms :—

Strongylus radiatus Rud., 1803, pp.
Strongylus radiatus Rud. of Schneider, 1866
Dochmius radiatus (Rud.) Leuck, 1868.
Uncinaria radiata (Rud.) Raill., 1885.
Monodontus phlebotomus Raill., 1900.
Bunostomum phlebotomum Raill., 1902.
Bunostomum radiatum (Schneider) Linst., 1906.
Bustomum phlebotomum Lane, 1917.

Hosts : This parasite has hitherto only been recorded from bovines, but among the material examined were three specimens kindly loaned by Prof. Yorke and labelled from *Sheep*.

Distribution : Probably universal. There is no record, however, of it occurring in Britain. The species found in Scotland from bovines is *M. trigonocephalus*.

Owing to the shortage of material, it was found impossible to describe this species with the same detail as *M. trigonocephalus*. Accordingly only the differences from that species are noted.

The length of the female varies from 16 to 21 mm., while the male has a maximum length of 15 mm.

The dorsal " tooth " is much shorter and blunter than in the type species. The ventral teeth are as in *M. trigonocephalus*, but the subventral teeth, which are only present in some specimens of that species, are constant here. They vary in size considerably, and those figured were

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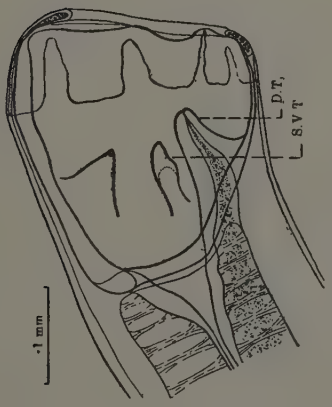

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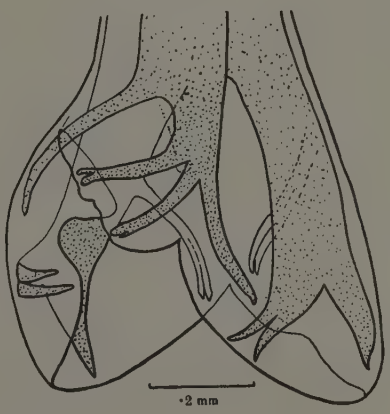

M. Phlebotomus. Fig. 17. *Buccal capsule, lateral view.* Fig. 18. *Bursa, dorsal view.*

the largest seen. This variability emphasises the inadvisability of adopting this as even a specific character. The nerve ring, excretory pore, and cervical papillæ are all about the same level, but are more anterior than in the type species.

The male bursa is similar to the type. The right externo-dorsal ray, however, seems to arise at the base of the dorsal ray, but there were not sufficient specimens available to state if this is absolutely constant. The dorsal ray splits into two branches, each of which ends in two or three digitations. All the rays are slightly heavier than in the type species.

The spicules, which are constructed on the same general plan as in *trigonocephalus* are very much longer, and measure from 3.5 to 4 mm.

The female tail is longer and more slender than in the type. The genital system is similar to *trigonocephalus*, but slight differences are noted. The coils of the uterus, which approach each other in the type, not only touch each other here, but in some specimens actually cross, so that cross sections might show four uterine tubes at the same level. The ovejector, instead of being straight in outline, is swollen just before the junction of its two parts where there is a decided constriction. The vagina is very long, and forms a small coil leading into a normal vulva.

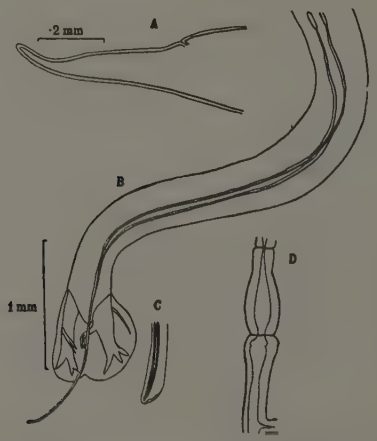

Fig. 19. M. *Phlebotomus*. A. *Female, posterior end.* B. *Male, posterior end.* C. *Termination of spicules.* D. *Ovejector.*

In 1917, Lane created a new genus *Bustomum* (type *B. phlebotomum*), which differed from *trigonocephalum* only in the presence of a pair of sub-ventral lancets. In the foregoing description of *trigonocephalum* it has been noted that a pair of sub-ventral lancets are occasionally present in otherwise typical specimens. In *phlebotomum* also, these lancets, while always present, vary somewhat in size. This character cannot accordingly be accepted as even of specific—much less of generic—value, and consequently the genus *Bustomum*, as defined by its author is invalid. The

other characters which differ *phlebotomum* from *trigonocephalum*, viz., length of spicules, shape of ovejectors and female tail, are of not more than specific value. In our present state of knowledge this species must be regarded as belonging to the same genus as *trigonocephalus*.

MONODONTUS LONGECIRRATUS (Linst., 1879) Ransom, 1911.

This species was recorded once from the Yak by v. Linstow. Its systematic position is uncertain. A single ventral ray is shown in v. Linstow's figure ; but this may be a mistake on the part of the author for two rays close together and parallel, such as occur in *Monodontus* (s. str.). The externo-dorsal rays are unequal in length, but are shown as rising symmetrically at the base of the dorsal. (*Both* externo-dorsals are present in the figure, not one only as surmised by Lane.) This also may be a mistake by v. Linstow as the rays are shown *unequal* in length. The dorsal ray, however, is unpaired ; and even admitting the two previous characters as misinterpretations, this character renders it doubtful whether it really is a member of this genus. It is, however, provisionally left in this genus.

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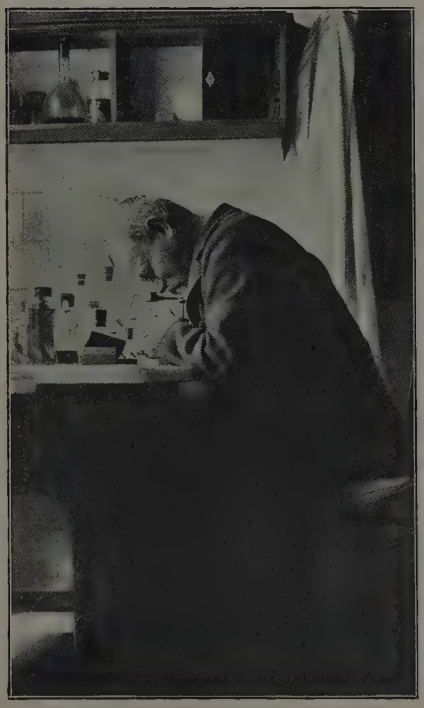
OBITUARY.

We record, with profound regret, the death of Dr. Arthur Looss, Ph.D., at Giessen, on the 4th May, 1923, after a long illness. Born at Chemnitz in 1861 Dr. Looss was educated at Lodz and Liepzic. After graduating as Doctor of Philosophy in 1885 he was appointed *privat docent* in the University of Liepzig. Later he was sent by Leuckart to Egypt where he discovered skin infection in Ankylostomiasis, which forms the basis of the preventive measures now in operation throughout the tropics.

As Professor of Parasitology at the Government School of Medicine in Cairo he carried out a remarkable series of studies upon the structure, classification and life-history of helminths, which revolutionised the subject and gained for him an imperishable name.

At the height of his fame—prestige and usefulness in 1914—the outbreak of the War brought his professional career to a sudden close. Political exigencies, uncaring for the trite half-truth that "Science knows no frontiers," drove him from his laboratory, library and collections. Separated from these, with failing health and meagre income, Looss passed the last few years of his life in a humble position in the University of Giessen, planning, with proud unbroken spirit, to give future service to humanity.

R. T. L.



Prof. A. Looss.

Journal of Helminthology, 1923. *Vol.* I., *pp.* 119-140.

The Life-History of *Syngamus trachealis* (Montagu) v. Siebold, the Gape-Worm of Chickens.

By R. J. Ortlepp, M.A., Ph.D., F.Z.S.

Introduction.

The investigations recorded below are a continuation of work started by Miss M. Turner, M.Sc., during her tenure of office in this department as Research Assistant under the Ministry of Agriculture Scheme. When she left for India, Prof. Leiper, F.R.S., requested the writer to carry on the investigations on the life-history of this parasite; it is with pleasure that he takes this opportunity to express his indebtedness and thanks to Prof. Leiper for his valuable suggestions and criticisms.

Nomenclature.

The first authentic account of this parasite is due to Weisenthal who gave a description of it in a letter to Marshall. The latter had the description published in the Medical and Physical Journal, 1797.* Weisenthal's description and figures, although imperfect, are yet sufficient to identify his worms as *Syngamus trachealis*. He, however, failed to observe the characteristic forked appearance of the adult worms.

Montagu (1811), apparently unaware of Weisenthal's description, describes this parasite as *Fasciola trachea*. As he failed to determine the Nematode nature of this worm, it is perhaps of interest that his description be given *in extenso*; it reads as follows:—"Body round, acuminated at the posterior end, the lower aperture produced on a long stalk or arm, that extends rather beyond the anterior end of the body where the other aperture is placed, and is not above half the size of that part: these openings spread a little, or are subinfundibuliform; the larger appears to be the mouth, and is slightly sexpartite; that on the other arm is used as a sucker, and is the part by which it adheres to the inside of the trachea: the divarication takes place at about one-fifth part of the length of the body: the colour is red, and the intestines, which are extremely numerous and tortuous, are white: the length is about an inch, and the breadth not above half a line."

* Waite (1920) has copied the whole communication and figures in his paper.

The editors, in a footnote to the above description, refer to Weisenthal's account, and think that the two descriptions apply to the same parasite, despite the fact that Weisenthal does not mention the presence of the "arm."

In 1793, Rudolphi had published a description of a Trematode obtained from the large intestine of chickens which he named *Distomum lineare*. In his Synopsis (1819), after discussing the descriptions of Weisenthal and Montagu, he comes to the conclusion that *Fasciola trachea* is the same as his *D. lineare*.

Von Siebold (1836) was the first to recognise that this parasite was a Nematode, in which the male and female are in permanent copula, despite the fact that he was unable to find an anus and that the cuticle was smooth. He does not agree with the editors of Montagu's article in considering the parasite described by Montagu to be the same as that described by Weisenthal; neither does he agree with Rudolphi in considering *F. trachea* as being synonymous with *D. lineare*. Rud.

Von Siebold was unable to place this worm in any known Nematode genus and, consequently, he created a new genus—*Syngamus*—for its reception.

On comparing Rudolphi's and Montagu's descriptions, the outstanding feature is the difference of habitat; Rudolphi's specimens were found in the large intestine, whereas Montagu's occurred in the trachea. The characters mentioned by Rudolphi which are characteristic of *S. trachealis* are (1) its red colour, and (2) the fact that the worm becomes white after having been placed in water for some time. The other characters mentioned could, however, also apply to *S. trachealis*. Is it possible that Rudolphi was dealing with worms which had been coughed up by the chicken, then swallowed, and the bird soon after killed? To the writer it appears hardly possible that the worms would have passed through the gizzard uninjured, but, as the hosts were young birds, the gizzard lining would not yet have attained the hardness of the adult bird, and consequently it might be possible for the worms to pass through it uninjured. Suppose this to have been the case, then how does his description fit in with the modern conception of this parasite? Rudolphi, in addition to the two above-mentioned characters, gives the following:—(freely translated)

1. Length 5-7 lines, breadth 1 line ($\frac{5}{12}$-$\frac{7}{12}$th inch × $\frac{1}{12}$th inch).
2. Head small, somewhat rounded, with six papillæ round the mouth.
3. Ventral sucker (porus subcentralis) large and distant.
4. Male genital visable to the naked eye.
5. Body margin straight and entire.
6. Tail blunt.

Taking these characters in order we find that (1) can very well apply to young worms; that (2) differs somewhat in that the head is small, but the presence of six papillæ round the mouth, however, are very suggestive of the six indentations round the mouth of *S. trachealis*, these structures appearing very much like papillæ when examined with a low power lens; that (3) can apply to *S. trachealis* if Rudolphi mistook the place of attachment of the male as being the ventral sucker; that in (4) Rudolphi mistook the male for the protruding cirrus: as he was supposedly dealing with a Trematode he would have expected the worm to be hermaphrodite, and in many Trematodes the cirrus does protrude; that (5) and (6) can both apply to *S. trachealis*. We see thus that all the characters of *D. lineare* can apply to *S. trachealis* and the question arises whether the two names are not synonymous. In this connection it is worthy of note that in 1861 Cobbold published his "Synopsis of the Distomidæ" wherein he lists Rudolphi's species as a member of Dujardin's genus *Crossodera* (renamed *Bunodera* Railliet). He does not give any reasons for so doing, but evidently the presence of six papillæ round the mouth suggested this course, in that in the genus *Bunodera* prominent papillæ or fleshy lobes surround the mouth. The most important of the other characters mentioned by Rudolphi can, however, not apply to *Bunodera*, for in this genus the body is not red, and consequently cannot turn white in water, and the cirrus is small and certainly cannot be seen with the naked eye; besides the members of this genus are almost exclusively fish parasites. When we also take into account the fact that a parasite from the intestine of chickens agreeing with Rudolphi's description had not been found prior to the appearance of Rudolphi's account, nor has it been found since, then the chances appear to be very great in favour of the view that Rudolphi was dealing with a parasite which was not in its normal habitat, *i.e.*, he was dealing with a displaced *S. trachealis*. However, as it is not possible to definitely decide on this point without a re-examination of Rudolphi's

types, if they exist, it seems advisable to retain Montagu's name, especially also as his name is so applicable to this parasite.

After the appearance of von Siebold's article, Nathusius (1837) obtained several specimens of syngami from the trachea of a black stork; only two pairs of these were in copula, several being free. On examining the free males he noticed the presence of a bursa which von Siebold had not observed, and from this fact concluded that the worms described by von Siebold and those obtained by himself belonged to the genus *Strongylus*; he therefore renamed the parasite *Strongylus trachealis*. Von Siebold (1837) was satisfied with Nathusius' conclusion, because on re-examination of his own specimens he was able to confirm Nathusius' finding of a copulatory bursa in the male; he, however, did not agree with Nathusius in regarding Nathusius' *Strongylus trachealis* as being specifically the same as his own specimens.

Dujardin (1845) revived the genus *Syngamus* and placed both von Siebold's and Nathusius' specimens in the same species.

In 1851 the genus *Syngamus* was again suppressed, this time by Diesing who placed it as a synonym of *Sclerostomum* Rud. He does not give any reasons, but in a note to his generic diagnosis of the genus *Sclerostomum* he states that in the members of this genus the male bursa become cemented on to the female during copulation; the fact that this is also the case in the genus *Syngamus* was evidently his reason for suppressing the genus. He renamed von Siebold's *Syngamus trachealis* *Sclerostomum syngamus*, and Nathusius' specimens he named *Sclerostomum trachealis*; as synonyms to the first of these two species he listed Weisenthal's specimens, and also *Fasciola trachea* Montagu and *Distomum lineare* (*trachea*) Rudolphi.

From Diesing's time up to the appearance of Megnin's articles this parasite was referred to as either *Syngamus trachealis* or *Strongylus trachealis* or *Sclerostomum syngamus*. Megnin (1883) re-studied the anatomy and came to the conclusion that von Siebold's genus was warranted. From Megnin's time up to the present there appears to have been no doubt as to the validity of the genus *Syngamus*.

Life-History.

(*a*) Previous investigations.

The most important researches on the life-history of the Gape-Worm are those of Megnin and Walker. Megnin (1883) carried out his investigations with material obtained from pheasanteries in France, whereas Walker (1886) obtained his material from chickens in America. Megnin's work, exclusive of its historical, anatomical and prophylactic parts, may be briefly summarised as follows :—The eggs cannot leave the body of the female except by the rupture of its body, the vagina being too small and being blocked by the bursa of the male ; they can develop *in utero* until the stage of the " perfect " embryo is reached ; all the developmental stages can, however, only take place in the larger individuals : thus 10 mm. long females contain fully formed but unsegmented eggs ; when 15 mm. long the eggs have already passed through the morula stage, and in some the embryo has begun to form ; when 20-22 mm. long the eggs in the uteri contain " perfect embryos rolled up inside them, and moving about inside their narrow prison." The eggs never hatch inside the body of the female ; they only do so after the female is dead and the body has become decomposed, and then only if the temperature and moisture are favourable. The larvæ so liberated can live for a considerable time in water. Young pheasants become infected by taking in these larvæ either in contaminated food or in their drinking water, or else by swallowing mature syngami which have been coughed up by infected birds. The larvæ bore through the digestive tract and pass into the aerial sacs and bronchi where they pass through the " Nymph " stage, after which they enter the trachea where they become adult. Megnin definitely states that no intermediate host is necessary in the life cycle.

Walker's aim was to find how infection spread and whether it was not necessary for the larvæ to pass through some intermediate host prior to their reaching the final host. He fed chickens with earthworms, slugs and sow bugs (*Oniscus asellus*) obtained from the vicinity of the coops of infected chickens, and found that those chickens which had been fed earthworms contracted the disease. He repeated his experiments with earthworms and in all cases obtained positive results ; he next fed chickens with earthworms obtained from soil on which no

infected chickens had been running, with the result that they did not contract Gapes; he, therefore, came to the conclusion that earthworms play a very important part in the transmission of this disease. On dissecting earthworms from infected soil, he found them to contain parasites which he took to be the larvæ of *Syngamus*. Some of these larvæ he cultured in calf's serum at 37°C. for several days; they grew in size, moulted, and although they did not reach the final stage, he considered them to be far enough advanced to be recognised as *Syngamus*. The earthworms become infected by taking in soil contaminated with Gape-worm larvæ. The larvæ take from 17 to 21 days to hatch, the time varying with the temperature. Walker also showed that it was not essential for the larvæ to go through the earthworm, because he was able to induce infection by simply feeding with hatched larvæ. The larvæ reached the trachea in about 7 days after feeding; he believed that in order to reach the trachea the larvæ bore through the œsophagus, as he had seen larvæ emerging from the œsophagus, then into the lungs, where they were found in various stages of development, and from here into the bronchi and so to the trachea; they reached maturity about 14 days after feeding.

In order to test Megnin's contention that infection could take place by eating mature Gape-worms, Walker fed adult *Syngami* to a chicken, but no infection resulted. He also showed that, however well developed the *Syngami* may be, the eggs never develop as far as the embryo stage inside the body of the living female; he also showed that the living worm can pass eggs, and that these do not undergo any further development during their passage through the intestines of the host.

Prior to the publication of his article, Walker submitted his results to Salmon, Chief of the Bureau of Animal Industry, United States Department of Agriculture. He also supplied the Bureau with earthworms obtained from infected soil; these worms were fed to 7 chickens, only 2 of which contracted Gapes. Of 5 chickens fed with newly-hatched larvæ only 1 became infected. Salmon (1885) published the results of these two experiments together with those of Walker, and concludes that whereas Walker obtained positive results by both methods of infection, his efforts resulted in only a partial success.

Recent investigations by Waite (1920) on the importance of earthworms as carriers of Gapes, has served to fully support Walker's

conclusion. Waite concludes "that earthworms are the important factor in the transmission of Gapes, as contended by Walker, rather than being of secondary importance, as assumed by Salmon."

(*b*) WRITER'S INVESTIGATIONS.

(1) *Sources of Material and Methods of Culture.*

The material used was solely from British birds, and was from two sources, namely chickens and turkeys. Turkey heads and gullets were kindly supplied to the Institute by Messrs. Harrods, Ltd., London, to whom the writer wishes to express his cordial thanks. Most of the turkey material had been in cold storage for some time, but this in no way affected the vitality of the eggs of the parasites as these developed and produced larvæ as vigorous as those developed from fresh material. The incidence of infection in turkeys appeared somewhat low, 81 trachea being examined, of which only 5 contained Gape-worms; 7 worms were collected from this source, the most obtained from one trachea being two pairs. Live infected chickens were sent to the writer by various poultry breeders. At first cultures were made from the eggs passed in the fæces; this method was, however, eventually abandoned in favour of collecting the eggs direct from the uteri of the worms, as the collecting of eggs from the fæces was found to be too tedious. For this purpose the uteri were dissected out of the parasites and the contained eggs placed in a shallow glass receptacle with just sufficient tap water to cover them; the receptacle was then placed inside a petri dish containing a little water, covered with another petri dish and the whole placed in a 22-27°C. incubator; once a day the water in which the eggs were immersed was replaced, and at the same time the eggs were agitated, either by passing them in and out of a pipette, or by stirring them with a needle. This procedure was followed in order that the water may be as well aerated as possible, it having been found that development of eggs was not so satisfactory in badly aerated water.

The eggs passed in the fæces of chickens were found to be in the same stage of development as those inside the uteri of the worms, namely in the 8-16 celled stage; in all the many adult worms examined, some over 30 mm. in length, eggs containing "perfect" or even developing embryos were never observed; Megnin definitely states that all stages of develop-

ment of the embryo can be seen in the uteri of large adults; Walker disproved this assertion and the writer's observations support Walker. Another statement of Megnin's which to the writer appears untenable is that the female never passes eggs during life; Walker doubted the correctness of this view as he obtained eggs from the fæces of chickens harbouring live parasites; Sheather and Shilston (1920), working with *Syngamus laryngeus* of cattle, observed the actual laying of eggs by keeping living worms in 0·4 per cent. salt solution; they observed that the eggs were ejected with some force from under the posterior flap of the caudal bursa. The writer has repeated Sheather and Shilston's experiment, using *Syngamus trachealis* instead, and is consequently able to confirm these workers' observations. They rightly state:— "It would appear to be a very wasteful procedure on the part of Nature if, as has been suggested, the eggs can only escape as a result of rupture or disintegration of the body of the female. This would be tantamount to the death of the parent worm. A very large proportion of the eggs liberated would in all probability not be viable."

(2) *Development of the Embryo.*

As already stated the eggs in the fæces are already in the 8-16 celled stage (Fig. 1A); they have a very characteristic shape for a Strongyle egg, being oval, .078–.091 mm. long by .043–.046 mm. broad, and having both extremities of the shell thickened to form a cap which, when the embryo is fully formed, becomes detached and so affords exit to the larva. In development the egg passes through all the typical stages of cell division seen in other Nematode eggs. During the second day of incubation the embryo begins to form; on the third it is already coiled, and on the fourth the first indications of a cuticle can be observed; on about the seventh the embryo begins to moult, the cuticle becoming completely separated on the eighth or ninth day. The embryos are now fully developed, being in the infective stage, and begin to hatch.

Hatching takes place by the embryo pushing its way through one of the openings in the shell caused by the displacement of the polar caps. The embryo, in the majority of cases, emerges in the ensheathed condititon, the sheath being left inside the shell in relatively few cases. From the examination of numerous developing eggs it has never been possible to observe more than one ecdysis; it would therefore

appear that the embryo passes through only one moult before reaching the infective stage. In this respect it resembles *Heligmosomum muris* as studied by Yokogawa (1922), and differs from *Ancylostomum duodenale* (cf. Looss 1911), *Hæmonchus contortus* (cf. Veglia 1916), and *Bunostomum trigonocephalum* (cf. Hesse 1923) where the larvæ only reach the infective stage after the second moult. A similar condition has been observed by the writer in the larvæ of the snake Ascarids *Ophidascaris filaria* and *Polydelphis attenuata*.

In order that the eggs may hatch easily, it is essential that they be kept at a temperature of at least 25°C. ; in cultures kept a few degrees below this temperature only a few eggs hatch ; while in those kept below 20°C. none were observed to hatch. On the other hand

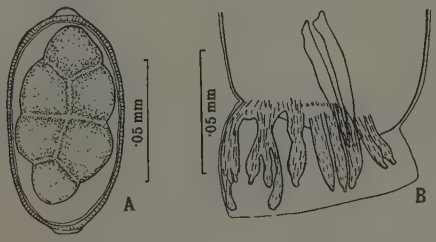


Fig. 1. *Syngamus trachealis*. A. Egg from fæces of chicken.
B. Caudal end of young male prior to copulation.

eggs which had been kept for some time below 20°C. hatched freely when exposed to a temperature of 29°C. This phenomena raises the question as to whether it is necessary for the eggs to hatch prior to the larvæ becoming infective. The writer is satisfied that it is not essential, because he has been able to produce infection by feeding chickens with mature but unhatched eggs. Hatching at these higher temperatures thus appears natural, because eggs taken into a bird would be submitted to a higher temperature, and it would therefore be to the advantage of the parasite if they then hatched easily. Megnin observed that the embryos are more vigorous at higher temperatures, but that at about 25°C. it takes from 28-30 days for the eggs to reach maturity and hatch. Walker found that it took about three weeks for the embryos to attain maturity when incubated in a warm room with a temperature varying

from 65-70°F., but has observed them hatching on the 17th day. The writer, when incubating his eggs at 25°C., has always had mature and hatched larvæ on at most the 10th day. It is, however, necessary to state that on this date only about half the eggs hatch, some even remaining unhatched after a month's incubation.

(3) *Morphology of the Infective or Second Stage Larvæ.*

As has been stated above, the larvæ in the majority of cases are hatched in the ensheathed condition. Some little time after many of these larvæ lose their sheaths but no change in their anatomy takes place until they find their way into the body of their host.

The hatched larvæ (Fig. 2A) are elongated eel-like organisms, thickest in their middle third, tapering slightly in their anterior third, and more so in their posterior third where the body is terminated by a sharp and pointed tail. They vary in length from .281 to .286 mm. with a maximum thickness of .0144 to .0156 mm.; Megnin's measurements are .28 mm. long by .013 mm. thick; and Walker's are .278 mm. long by .0126 mm. thick (.011 inches × .0005 inches). The cuticle is very finely striated transversely, and in its mid-lateral lines, on either side, it is slightly raised along the whole length of the body; these ridges represent the position of the lateral lines.

The anterior extremity of the body, round about the first quarter of the buccal cavity, constricts sharply so that this part is only about three quarters the diameter of the body immediately behind it (Fig. 3A). No buccal papillæ were observed. Behind the anus the body tapers gently to form a fine pointed tail which is nearly 1/11th of the body length.

The mouth leads into a narrow buccal cavity whose wall is cuticularised, and in optical section appears as two fine refringent lines thickened at the junction of their 1st and 2nd quarters. The œsophagus is relatively long and forms just less than 2/5th of the body length; it is more or less claviform in shape with the nerve ring encircling it just anterior to its middle. It thickens gradually from the mouth to the level of the nerve ring where it narrows suddenly to about 2/3rds of its thickness; from here it thickens only very slightly until towards its posterior end where it broadens out to form a conspicuous and pyriform bulb; no œsophageal valves were detected. The intestine is slightly longer than

Fig. 2. Second, third and fourth stage larvæ of *Syngamus trachealis*.

A. Ensheathed second stage larva. B. Anterior extremity of transitional second stage larva
C. Third stage female larva. D. Ensheathed young fourth stage male larva.
E. Posterior extremity of transitional second stage larva.

the œsophagus, and its origin is as wide as or slightly less than the base of the œsophageal bulb. It is densely packed with refractile globules, in consequence of which it was not possible to determine its component cells. On its ventral surface, just posterior to its middle, its cells are indented by the lens-shaped genital primordium, which appears to consist of two cells, each shaped like an isosceles triangle, applied to each other by their bases. From the posterior end of the intestine a thin, oblique and sometimes wavy line, represents the rectum; it opens to the exterior about .026 mm. from the posterior extremity.

The excretory system is represented by a fine line running nearly parallel to the œsophagus, and then turning sharply ventral-wards to open to the exterior a short distance posterior of the nerve ring; in some larvæ the posterior end gave the suggestion that it widened out to form an oblong vesicle lying ventral to and slightly anterior to the œsophageal bulb.

The body cavity is well developed, and its intestinal region, in newly hatched larvæ, is densely packed with what appear to be oil globules; these form a layer round the intestine and the base of the œsophagus; in larvæ 14 days or more old these globules have to a great extent disappeared, thus suggesting that they may represent stored food material.

(4) *Biology of the Infective Larvæ.*

Newly hatched larvæ are fairly active at a temperature of 25°C., but not so active as those of *Ancylostoma duodenale* or *Hæmonchus contortus*. After a few days their activity slows down considerably so that at about the end of a week hardly any movement is noticeable, except a slight shifting of the head and tail. They differ from the larvæ of the worms referred to above in that they do not show any tendency to climb out of the culture vessels, and also in that their capacity for resisting dryness is only very slight. Ensheathed and unensheathed larvæ, when placed on a slide and allowed to dry for an hour, do not show any signs of reviviscence when water is applied to them; they can, however, live for a long time when placed on a slide without water provided the slide is placed in a humid atmosphere; larvæ placed under this condition have been found to be still alive after 14 days.

When a heated glass rod is gently applied to the under surface of a slide on which larvæ in water have been placed, the larvæ show only a moderate response ; they become slightly more active, especially those which are in a dormant condition ; they do not, however, show any tendency to swim towards the source of heat as is the case with Ancylostome larvæ.

It was possible to show that the larvæ do not penetrate the skin, in that larvæ which had been placed on a piece of baby mouse skin and watched under the microscope, did not show any tendency to bore into it ; the skin had been stretched over a ring of cork and floated in warm normal saline (37°C.). A known number of larvæ were left on the skin overnight by placing the container in an incubator (37°C.) ; in the morning all the larvæ were recovered by flooding the skin and pipetting off the liquid, thus showing that none had entered the skin. (*Goodey's Method.*)

(5) *Infection and Methods of Examination.*

As a rule a mixture of mature eggs and larvæ in water were administered orally by means of a drawn-out pipette, the larvæ being squirted into the back of the mouth. This direct method of infection was the only one employed, infected earthworms not being available. By this method it was possible to obtain nearly 100 per cent. infection, only 2 chickens out of 22 remaining uninfected after 14 days. This result proves that an intermediate host is not essential as claimed by Megnin ; it does, however, not take away any of the importance attached to earthworms as carriers as claimed by Walker and Waite ; indeed the writer, from the researches of these last two workers, is inclined to the view that under natural conditions more chickens would contract the disease by eating earthworms than by taking in eggs or larvæ in contaminated food.

In order to trace the development of the larvæ inside the body of the host, chickens were infected and killed at definite periods afterwards ; the organs were then carefully examined. At first, press preparations of fresh material of the lungs, liver and spleen and also sections of these organs were examined ; this method was eventually abandoned in favour of teasing the different organs in normal saline, and if any of them contained larvæ, then bits of them were fixed and sectionised in order to ascertain the position of the larvæ in the tissues. In all the experi-

ments only incubator hatched chickens were used varying in age from a few hours to 10 days old; they were kept in a special brooder divided into compartments. The larvæ obtained from teased organs were collected and some examined alive, the rest being fixed in hot 70 per cent. glycerine alcohol; after evaporation these latter were examined in glycerine. In infections of less than four days standing the blood and the contents of the body cavities and air sacs were also examined.

(6) *Fate of Second Stage Larvæ in Body of Host.*

Repeated experiments and examinations of viscera, normal saline washes of the body cavities and air sacs, and also of the blood extracted from the heart, have failed to reveal the course taken by the larvæ in order to reach the lungs. Megnin states that he found very active larvæ in the air sacs, "especially in the cavities which communicate with the duodenal part of the intestines"; he concluded that the larvæ reach the trachea by first boring through the œsophageal or intestinal coat and so getting into the air spaces, and from here by migration into the bronchi and so into the trachea. Walker thinks that the larvæ pierce through the œsophagus, pass into the pulmonary bronchi and so into the trachea; he has never been able to find any larvæ in the digestive tract below the œsophagus, but has found them beneath the mucous coat of the œsophagus and has also seen them emerging from this organ into the lung. Notwithstanding the observations of these workers, and the writer's negative results, the writer thinks the normal course will be found to be via the blood stream as is the case with Ascarid, Ancylostome and Heligmosomum larvæ. The writer has recovered larvæ from the lungs 24 hours after infection, and this period would appear somewhat on the short side if the larvæ have to go through a series of borings and migrations, whereas, they could easily reach their destination in this time if they were carried passively in the blood stream; the writer believes to find support for this view in that in sections of the lung of newly infected chickens, the larvæ were not found in the bronchi but were lodged in the alveoli, which would be the natural position to find them in if they had been carried there by the pulmonary arteries.

All second stage larvæ recovered from the lungs had lost their sheaths. They grow considerably in size during the second and sometimes part of the third days of infection, the largest attaining a length of .397 mm.

Except for a general increase in the size of the different organs, the larvæ still show the same characters as seen in the newly hatched larvæ. Towards the end of the second day a transformation takes place and the larvæ prepare themselves to pass into the third larval stage. This change is most marked at the anterior end where the œsophagus changes to one having a nearly uniform diameter, except at its base which is

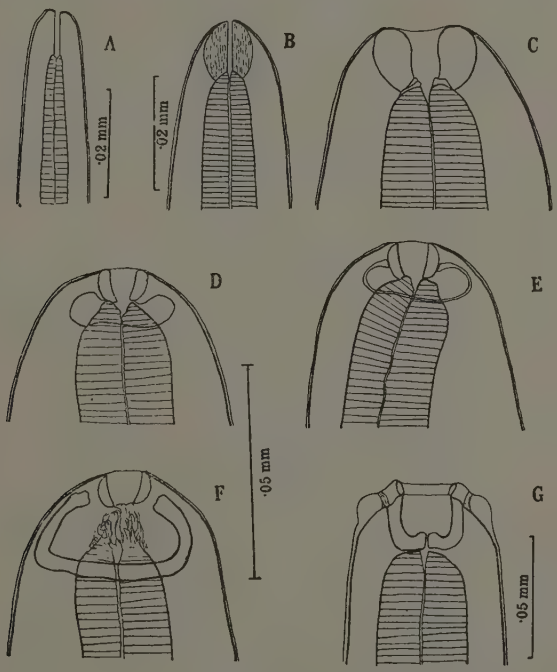


Fig. 3. Anterior ends of second, third and fourth stage larvæ, showing development of mouth capsule.
A. Second stage larva. B. Transitional second stage larva.
C. Third stage larva, showing larval mouth capsule.
D-G. Different stages in development of adult mouth capsule.
(*The scale alongside* A *refers also to* C *and that alongside* D *and* F *refers also to* E.)

thicker, and also becomes relatively much shorter, and where a new buccal capsule begins to develop round the buccal cavity. In the development of this capsule (Fig. 2B and Fig. 3A–C) an area, plano-convex in optical section, becomes delimited round the buccal cavity; its outer margin

becomes cuticularised and its central area at first becomes somewhat opaquer than the surrounding tissues, but eventually this opacity disappears and the whole central area becomes transparent. In the meantime a new cuticle has begun to form beneath the old one.

(7) *Third Larval or Second Parasite Stage.*

This stage is reached in the lungs during the third day of parasitic life. The old cuticle appears to rupture at any part of the body, because larvæ have been observed with the anterior or posterior end still partly ensheathed, the other extremity having already lost its covering. The most noticeable feature now is the presence of two types of larvæ, one possessing a pointed tail, the other an obliquely truncated one (Fig. 1, C and E); the former larvæ are destined to develop into females, the latter into males. The larvæ (Fig. 2, C and E) now increase considerably in the length and may attain a length of 14.2 mm. for the female and 1.16 mm. for the male. As the body grows the œsophagus becomes relatively much shorter in size, becoming in the mature third stage, female just slightly less than 1/6th, and in the male 1/5th of the body length.

The larval buccal capsule is simple and concavo-convex with a much thickened and transparent cuticular wall. It is about .009 mm. deep, and at its base, round the opening of the œsophagus, cuticular thickenings have been observed; these probably represent the rudiments of teeth.

The œsophagus is straight and of a more or less uniform thickness except at its base, which is thickened to form a bulb. The nerve ring encircles it at about its middle or just slightly further back.

The intestine passes straight back and its wall is composed of relatively few and large spindle-shaped cells (in optical section) with large nuclei; its lumen contains food particles consisting of blood corpuscles. The rectum is surrounded by a mass of cells of which three possibly represent the rudiments of the rectal glands; it opens to the exterior at .06 to .07 mm. from the posterior extremity in the females, according to age, and about .025 mm. from the end in the males.

The excretory pore is situated just anterior to the œsophageal bulb; it leads into a fine duct passing obliquely inwards and backwards which soon joins up with the anterior terminations of the two lateral cervical glands. The cervical glands are large and uninucleate and

lie one on either side of the intestine in its ventro-lateral areas ; in mature third stage larvæ they may reach half way down the body ; towards their posterior ends they become thickened, and in this thickening the large and oval nucleus is lodged.

The genital rudiments have by now undergone considerable development. In the females it has elongated both anteriorly and posteriorly, forming a solid organ thickened in its middle ; this middle portion is destined to develop into the uteri and the thinner terminal portions into the ovaries. On the ventral surface, in the centre of the thickened middle portion, a proliferation of the cells takes place which come in contact with the body wall, and causes a slight bulging to be seen on its outer surface. As development proceeds a cavity is formed inside this thickening, which represents the beginning of the vaginal cavity ; it does not open to the exterior during this larval stage. From the development it will thus be seen that the uteri are at first divergent ; it is only during the final stage that the anterior uterus turns backwards and runs parallel to the posterior one.

In the male the genital rudiment has developed and extended down to the rectal region. It now consists of a solid organ tapering abruptly towards the anus and gently towards its anterior end. The gradation stages from the more or less centrally placed genital primordium of the second stage larvæ to the well marked organ described above were not observed.

During the fourth day of parasitic life further marked changes take place at the anterior extremity of both sexes and at posterior extremity of the males. This marks the termination of the third larval stage. At the anterior end the larval buccal capsule becomes displaced by the development of the adult mouth capsule. At the posterior end of the males the accessory genital organs—bursa and spicules—begin to develop.

The first indication of the developing adult mouth capsule is the formation of an annular space round the junction of the larval mouth capsule and the œsophagus (Fig. 3, D-G) ; this space increases in size and its outer wall becomes cuticularised. As it develops it pushes forward the larval mouth capsule, and itself begins to assume the characteristic cup-shaped appearance of the adult mouth capsule. Its lower floor encircles the floor of the œsophagus so that part of this organ

juts into its lumen. Probably this projecting portion is eventually absorbed, as in one case it appeared to be in process of disintegration. The portion of the floor which adjoins the œsophagus becomes thickened into a rim from which the teeth, which are well developed as soon as the capsule is fully formed, are derived.

At the posterior extremity of the males (Fig. 2, D and E) a space appears between the post-anal body portion and the cuticle. Two wings of cells now become developed from the lateral margins of the ventral surface ; these extend for about the same distance in front of and behind the anus. From these flanges the bursa and its rays are developed. At the end of this parasitic stage the rays are already well marked and consist of the dorsal group, two lateral and two ventro-lateral groups. The spicules are developed from a mass of cells on the dorsal side of the rectum. These elongate and become cuticularised in two longitudinal and somewhat convergent lines. At the end of the third stage they are already fully formed.

While these changes have been taking place, the old cuticle has become detached from the body and a new one has been formed underneath it. In this separation the larval mouth capsule is also concerned, and when moulting takes place it is also shed.

(8) *Fourth or Final Larval Stage.*

Moulting takes place either towards the end of the fourth or during the fifth day of parasitic life. The larvæ now show in miniature practically all the principal characters of the adult. All the developmental stages up to now have been taking place in the alveoli of the lungs, where the larvæ have been feeding on blood derived from the epithelial blood capillaries. They now very soon migrate into the larger bronchi where, after a slight further development, the males and females copulate. At the time of copulation the genital organs in both sexes have not yet become fully developed, being mostly still in the solid condition. The earliest date on which copulating larvæ have been observed was on the fifth day after infection, and on the seventh day they had already made their appearance in the trachea. These copulating larvæ were already 1.98 mm. long for the female and 1.144 mm. long for the male ; the spicules of the latter could be seen inserted into the vagina of the female.

The bursa of the male is best studied in fourth stage larvæ before copulation has taken place. In older forms the bursa becomes so intimately united to the body of the female that it is almost impossible to separate it without tearing. In young forms the bursa is in a straight line with the longitudinal axis of the body; after copulation it bends forward and dorsalwards and forms an obtuse angle with the body. The bursa is shallow and cup-shaped, with an entire margin deeply indented on its ventral side. The dorsal ray is divided almost to its base, and each branch carries three somewhat clubbed digitations; the number and place of origin of these is liable to vary, one branch sometimes carrying two and the other four digitations. The externo-dorsal rays have their origin separate from the dorsal, and run more or less parallel to it; they generally show a constriction behind their middle, and terminate in nipple-like points some distance from the edge of the bursa. The lateral rays are grouped together and run parallel to one another; the medio-lateral is slightly thinner than the other two. The ventral rays are parallel and much slenderer than the other rays; as a rule their terminations are also nipple-like. The spicules are small, straight and taper to fine points; in the adult they are difficult to make out because of their delicacy. They are .06 mm. long.

The chickens up to now had shown no ill effects caused by the larvæ in the lungs, in fact the first symptoms of the disease did not manifest themselves before the ninth day. Lungs containing larvæ did not show any of the hæmorrhagic spots seen on the surface of Ascarid-infected lungs, neither did they appear congested in section.

Megnin and Walker both state that they had found developmental stages in the lungs, but apparently neither had found the third stage larva. From Megnin's brief description and drawing it is clear that the larvæ he obtained were young final stage larvæ. Walker does not give any description of the forms found by him.

After reaching the trachea the parasites grow rapidly in size and attain sexual maturity in from 10 to 14 days later, as is evidenced by the fact that chickens begin passing normal eggs in their fæces from 17 to 20 days after infection. This period is slightly longer than that given by Walker, who gives 14 days, but it is possible that he calculated his date from the first appearance of the eggs in the fæces of the chicken; the writer, however, observed that the first formed eggs are generally

abnormal, being mostly vacuolate; this possibly would explain the slight differences in the time required.

From the above records it will be seen that it is possible for the whole life cycle to take place in about four weeks, *i.e.*, one week for the development of the eggs, and two and a half to three weeks for the larvæ to pass through all the developmental stages and attain sexual maturity in its host.

Summary and Conclusions.

(1) The female can and does *lay* eggs.

(2) The eggs in the body of living worms do not develop beyond the 16-celled stage.

(3) The eggs passed in the fæces of chickens are in the same stage of development as those in the uteri of the adult.

(4) The eggs take about a week to develop and produce infective larvæ, when cultured in well aerated water at a temperature of about 25°C.

(5) The embryos undergo only one moult before reaching the infective stage.

(6) The second stage or infective larvæ are generally ensheathed. They are non-climbers, do not penetrate the skin, and cannot resist dessication.

(7) In the body of the host the larvæ soon reach the lungs, where they grow considerably in size and undergo two further moults.

(8) The final or fourth stage larvæ are reached in about five days after infection.

(9) The larvæ then copulate and migrate into the trachea where they attain sexual maturity in from 10 to 14 days later.

(10) The whole life cycle is completed within a month.

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A preliminary note on the second intermediate host of *Heterophyes* in Egypt

By M. Khalil, M.D., Ph.D., M.R.C.P.,

Asst. Director of Investigation in Ankylostomiasis and Bilharziasis, Cairo.

Japanese observers have found the encysted cercariæ of *Heterophyes nocens* in the Japanese mullet which belongs to the genus *Mugil*. In Egypt, *Heterophyes heterophyes* is a fairly common parasite of man, dog and cat. The genus *Mugil* "Egyptian mullet" is represented in Egypt by three species.

It was thus probable that the parasite encysts in one or more of these species.

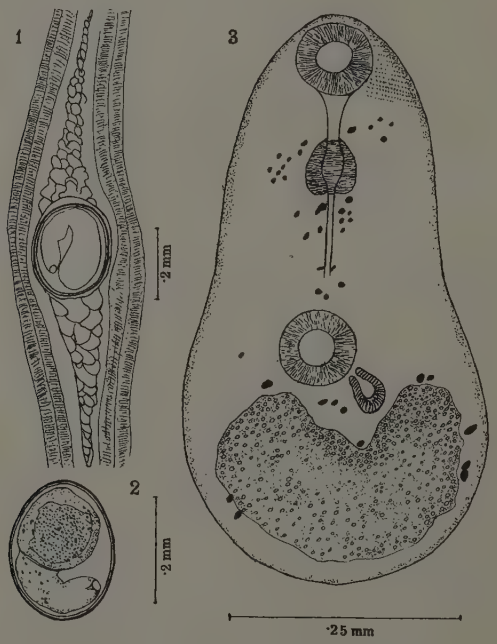
The species of *Mugil* live particularly in the lakes adjoining the Mediterranean coast. At certain times of the year they swim up the Nile. The specimens secured for examination belong to *Mugil cephalus*, caught at Lake Manzalah adjoining Port Said.

Encysted cercariæ were looked for on the scales, fins, tail and gills with negative results. On examining the flesh a fair number of encysted cercariæ were found in one specimen only.

The cyst is enclosed in a spindle-shaped area midst the muscle fibres. This area is filled with highly refractile fat globules. The cyst is enclosed in a thin membrane from which it can be liberated by pressure on a cover slip preparation. The cyst wall is very resistant. It encloses the folded distome which is highly active, moving round and round. The distome can be liberated by pressure on the cover slip sufficient to break the cyst wall. Once liberated this trematode is very active and fixes itself to the surrounding muscle fibres. The accompanying three camera-lucida drawings show the main anatomical features. The presence of a genital sucker adjoining the ventral sucker was suggestive of the parasite being the larval stage of *Heterophyes* and probably that of the type species *H. heterophyes*. Feeding experiments on animals which have been carried out on cats confirm this. Eight

days after feeding immature *Heterophyes* were found in the gut and eggs were passed on the fourteenth day. The adults recovered were indistinguishable from *H. heterophyes*.

The scheme of research for *Heterophyes* followed in this paper was planned in London as a result of a discussion with Prof. Leiper to whom I am very much indebted.



Explanation of Figures.

Fig. 1. Encysted cercaria amidst the muscle fibres of *Mugil cephalus*. A spindle-shaped mass of fat globules surrounds the cyst.

Fig. 2. Cyst liberated by pressure from amidst the muscle fibres. The outermost envelope is left behind. The cercaria is folded on itself.

Fig. 3. Cercaria liberated from the cyst. Ventral and genital suckers are well defined.
An undifferentiated mass containing a large number of highly refractive globules lies at the posterior end of the body.
A large number of dark pigmented bodies are scattered throughout the body. These are possibly of the nature of chalk bodies similar to those found in cestodes and meant to neutralise the gastric juice of the final host.

Journal of Helminthology, 1923. *Vol.* I., *pp.* 143-156.

A Review of the Plant Parasitic Members of the genus *Aphelenchus*.

By T. Goodey, D.Sc.

Introduction.

Within recent years our knowledge of the plant parasitic nematodes of the genus *Aphelenchus* has been considerably increased, chiefly through the work of Ritzema-Bos (1891-1893), Marcinowski (1909), Molz (1909), Schwartz (1911), Cobb (1919), and Stewart (1921). The present writer has within the last few months had an opportunity of examining nematodes from strawberry plants affected by " red-plant " disease, which are undoubtedly *Aphelenchus fragariæ*, a species already known as the cause of " bunch " or " cauliflower " disease in strawberries.

The purpose of the present paper is to put this observation on record, and to bring together in a brief review the facts concerning the nematodes themselves with some account of their biology and the pathological symptoms produced by them.

An opportunity is also taken to discuss the question of suitable remedial measures to be applied in the case of these plant diseases, and the suggestion is made that some form of treatment by heat is likely to afford a radical remedy. This is based on the biology of the parasites and on their proved susceptibility to and death at comparatively low temperatures.

The genus comprises a large number of species, about 30, the large majority of which are free-living forms occurring in association with the roots of plants, in moist humus or in water. The writer has found them along with other saprophytic nematodes in clover seedlings attacked by *Tylenchus dipsaci* (1922a) and at one time they occurred in fair numbers in sour paste with *Anguillula rediviva* (1922b).

At the present time four species and one variety are recognised as pathogenic to plants, and are dealt with in this paper. Another species is here brought into the genus from the genus *Tylenchus*, to which it was wrongly assigned by its author Taylor.

Plant Parasitic *Aphelenchi*.

A. fragariæ Ritzema-Bos, 1891.

Endoparasitic in stem tissue of strawberry plants causing hypertrophy and production of " bunch " or " cauliflower " disease. Ectoparasitic in buds of strawberry, causing " red plant " disease.

A. cocophilus Cobb, 1919.

Endoparasitic in stem, leaf and roots of coco-nut palm in West Indies, causing " red-ring " disease.

A. ritzema-bosi Schwartz, 1911, syn. *phyllophagus*, Stewart, 1921.

Endoparasitic in leaves of chrysanthemums causing destruction and discoloration of leaf tissue.

A. ribes (Taylor, 1917) syn. *Tylenchus ribes* Taylor, 1917.

Ectoparasitic in buds of black currant, causing destruction of scale and true leaves of the bud.

A. olesistus Ritzema-Bos, 1891.

Endoparasitic in stems of ferns, begonias, and cypripediums, causing destruction and discoloration of tissue with production of blotches.

A. olesistus var. *longicollis* Schwartz, 1911.

Endoparasitic in stem tissue of cultivated violets, causing hypertrophy and gall formation.

General Morphology and Structure.

The following has been based very largely on Stewart's account of *A. ritzema-bosi* which has been worked out in greatest detail. All the members of the genus are very small and slender organisms, rarely attaining more than 1 mm. in length. The sexes are separate, and the females are generally slightly larger than the males.

The extreme anterior end of the body is slightly narrowed with the formation of a sort of cushion, with straight or slightly bulging sides,

whilst the tip of the tail, except in *A. cocophilus*, has a very small but distinct process.

The mouth is furnished, as in the nearly related genus *Tylenchus*, with a hollow spear or stylet, which is usually presumed to have a piercing function. The posterior end of the stylet is swollen into a tri-lobed bulb, and is followed by a narrow œsophagus which leads to a well marked muscular bulb. There is a posterior œsophagus which joins the intestine. This region of the body has been studied in detail by Stewart, who shows that the old view that the intestine commenced immediately posterior to the bulb is erroneous, and that there is a true post-bulbar œsophagus which has a round lumen, is embraced by the nerve ring, and is surrounded by a cellular collar. In this region also are to be found a pair of salivary glands, the outlets of which have not, however, been traced. The arrangement of the glands resembles somewhat that found by Cobb in *Tylenchus similis* (1915).

The intestine extends from the junction with the œsophagus to the anus. According to Stewart it has a flattened slit-like lumen. The walls of the intestine contain nuclei and granular material.

The excretory system consists of a single *renette* cell which lies over the anterior end of the intestine between the end of the salivary glands and the anterior extension of the gonad. It is furnished with a single large nucleus, and is presumably connected with the excretory pore which lies at the level of the nerve-ring or just behind it.

The female reproductive organ consists of a pre-vulvar ovary stretching forward in the body. The eggs pass into the uterus which leads into the anterior vagina, and is separated from it by a sphincter. There is a post-vulvar sac-like vagina which, together with the anterior vagina, serves as a receptaculum seminis. The vulva is a transverse slit situated a short distance behind the middle of the body.

The male reproductive organ consists of a single gonad in the form of an elongated mass of cells, which show various stages of division. Posteriorly there is a short vesicular seminalis. There are two small somewhat horn-shaped spicules and each consists of a paired dorsal piece and a single ventral piece united at the tip. There is no accessory piece, though Cobb speaks of an obscure one in *A. cocophilus*. The male tail is always distinctly recurved, which enables one to distinguish the sexes easily. The females produce eggs which undergo development

and give rise to larvæ ; these pass through a series of moults and periods of growth until maturity is reached. Stewart found that *A. ritzema-bosi* could complete its development from egg to egg in about 14 days under temperate conditions.

Details of Species, Symptoms and Biology.

A. fragariæ Ritzema-Bos, 1891.

Principal measurements in mms. :—

Length of body, female		0.665–0.893
,, ,, ,,	male	0.608–0.722
Breadth of body	...	0.013–0.015
Length of stylet	...	0.008–0.009
,, ,, spicules	...	0.013–0.015 dorsal portions.
,, ,, ,,	...	0.008–0.009 ventral portion.

Proportions, length/breadth α ; length/L. of œsophagus β ; length/L. of tail γ :—

Female, $\alpha = 44–59$, $\beta = 12–15$, $\gamma = 15–20$
Male, $\alpha = 46–55$, $\beta = 11–12$, $\gamma = 18–19$

The measurements show that this species is slightly longer and slenderer than *A. olesistus*. The excretory pore is at the level of the nerve ring. The anterior lip of the anus is rather prominent ; in all other respects it agrees in structure with the description already given.

Symptoms.—This organism is the cause of " bunch " or " cauliflower " disease in strawberry plants, in which it sets up hypertrophy of the tissues in the flower-stalks. It seems also to be responsible for the condition known as " red-plant " in the same host. In this connection the following points are worthy of note. In November, 1922, the writer received from Mr. J. C. F. Fryer, of the Ministry of Agriculture Pathological Laboratory, strawberry plants affected by " red-plant." On dissecting buds numbers of *Aphelenchus*, mostly immature forms, were found, the species of which were not determined. A note was made of the occurrence, and it was hoped that more material would be forthcoming for further study. However, no more worms from " red-plant " were seen until June, 1923, when tubes containing worms from the region of the growing-point of affected plants were sent to the writer for identification by Mr. E. Ballard, of the Research Station, Long Ashton, Bristol, who had taken up the investigation of the disease in the West of England.

Examination and measurement of the worms showed them to be identical with typical *A. fragariæ*, specimens of which taken from straw-

berry plants affected by " bunch " were sent at the same time. In the writer's opinion there is no doubt that " red-plant " is due to *A. fragariæ* ; this is the opinion also of Mr. Ballard and his colleague, who are bringing out a paper on their observations.

Biology.—The species can live as an ectoparasite, and has been found as such by both Marcinowski (1909) and Stewart (1921) in apparently healthy plants in the axils of the leaves and within the buds. That it can function as a true parasite in the buds is clear from the account just given. Under exactly what conditions it enters the stem tissues and sets up hypertrophy is not at present clear. Presumably it requires the presence of films of moisture for migration from the soil and upon the plant, such as would occur during light rain or mist.

A. COCOPHILUS Cobb, 1919.

Principal measurements in mms. :—

Length of body,	female	0.9 –1.1
,, ,,	male	0.82–1.05
Breadth of body,	female	0.013
,, ,,	male	0.009
Length of stylet	...	?
,, ,, spicules	...	0.012 dorsal portions.
,, ,, ,,	...	0.008 ventral portion.

Proportions :—

Female $\alpha = 83$, $\beta = 20$, $\gamma = 50$
Male $\alpha = 100–116$, $\beta = 20$, $\gamma = 27–35$

The above measurements are based on specimens obtained from material preserved in 70 per cent. alcohol, received by the writer in 1921 from Mr. W. Nowell. Cobb's original description (1919) contains measurements expressed in terms of his formula in which various regions of the body are shown in percentages of the body length. The reader interested in this system should consult Cobb's paper.

The worms are extremely slender as shown by the proportions given above. The female tail tapers gradually, not sharply as in the other species, and the tip of the tail has no process. The male tail is markedly curved, and is without terminal process. It possesses two post-anal sub-ventral papillæ and one pre-anal sub-ventral papilla.

From Cobb's description, the species appears to have the same general structure belonging to the genus. The posterior bulb of the stylet was only faintly discernible, and the region of the salivary glands was very difficult to make out.

The female reproductive organs were typical, possessing pre- and

post- vulvar vaginæ, the pre-vulvar vagina being separated from the uterus by a sphincter.

The male has spicules of the usual shape, and Cobb speaks of a single rather obscure accessory piece.

The organisms are so delicate that descriptions based on preserved material are inadequate, and, in the writer's opinion, the parasite should be re-examined and re-described from the study of perfectly fresh material.

Symptoms.—A. cocophilus gives rise to " red-ring " disease of the stem and roots of the coco-nut palm in certain islands of the West Indies: Trinidad, Tobago, and Grenada. A full account of the disease and of infection experiments is given by Nowell (1919 and 1920). The following is a short summary of the chief external and internal symptoms.

(*a*) Progressive yellowing and browning of the leaves, commencing at the leaf tip.

(*b*) The nuts, in a green condition, are shed slightly in advance of the discoloration of the leaves, and this, in some cases, is the first external symptom of the disease.

(*c*) Internally, the stem shows a well-marked complete ring of red tissue, usually 1–1½ inches wide, lying 1–2 inches from the periphery. This zone of tissue extends up the stem for about 4 feet, and then breaks into longitudinal streaks and scattered dots. Leaf stalks also show the red tissue either as a homogeneous mass or as red and yellow streaks and patches.

(*d*) The roots become affected in the cortex, which, instead of remaining white becomes dry and flaky, and undergoes yellowish or pinkish discoloration.

The constant and abundant association of the nematode with the diseased areas and the absence of any signs of fungal growth from these areas is noteworthy, and points clearly to *A. cocophilus* as the cause of the disease. Infection experiments have been conducted by Nowell (1920), in which portions of diseased stems have been inserted into holes bored in healthy palms, with the result that typical diseased conditions have been set up. Infection has also been produced by inoculation at the leaf base, and Nowell's final conclusion is that this is probably the natural mode of infection presumably taking place at an early stage in the growth of the palm.

Biology.—The habits of this species outside the host plant have not been studied. It is reasonable to suppose, however, that on the fall of diseased leaves, etc., the worms would ultimately find their way to the surface of the soil and the immediately subjacent layer and that infection of the young plant would take place by the migration of the worms, under suitable atmospheric conditions, on to the surfaces of the plant, followed by entry of the tissues either through stomata or wounds.

A. RITZEMA-BOSI Schwartz, 1911, *syn.* PHYLLOPHAGUS Stewart, 1921.

Principal measurements in mms. :—

Length of body, female	0.816–1.248
,, ,, ,, male	0.880–1.232
,, ,, stylet ...	0.008–0.009
,, ,, spicules ...	0.015–0.018 dorsal pieces.
,, ,, ,, ...	0.009–0.012 ventral piece.

Proportions :—

Female $\alpha = 34–54$, $\beta = 12–15$, $\gamma = 17–23$
Male $\alpha = 37–51$, $\beta = 11–15$, $\gamma = 24–37$

Stewart gives total lengths which are smaller than the above, viz. : Female, 0.923 ; male, 0.965.

It is distinguished from the other species by its greater size, by the presence of the excretory pore well behind the nerve-ring, and by the presence of a pair of small ventral papillæ situated about midway between the anus and the tip of the tail. The cushion-like cap at the extreme anterior end is more swollen than in the other species. Its general structure is that already given.

Symptoms.—It is parasitic in the leaves of chrysanthemums in the mesophyll spaces of which it lives, and gives rise to marked destruction and discoloration, with final falling of the leaves. Its effects are especially serious in certain varieties of greenhouse grown chrysanthemums, and it occurs in both England and Germany.

Biology.—The work of Stewart and others shows that this species has similar habits to *A. olesistus*, in that it migrates to the host plant from the soil, and wanders on the outside of the plant when the requisite moisture conditions are present. As showing that it moves on the outside, and not within the tissues of the stem, a plant with the stem ringed with vaseline and growing in infected soil remained free from parasites. It would appear, also, that both *A. olesistus* and *A. ritzema-bosi* have a limited power to withstand dessication in that they can only live in the soil for about 50 days (c.f., *A. ribes*, p. 151).

A. RIBES (Taylor, 1917) *syn.* TYLENCHUS RIBES Taylor, 1917.

Principal measurements in mms. :—

Length of body, female	0.92
Breadth of body, „	0.04

Proportions :—

Female $\alpha = 23$, $\beta = 14$, $\gamma = 13$
Male $\alpha = 24$, $\beta = 13$, $\gamma = 15$

The proportions given have been computed from measurements made of the drawings given by Taylor; her paper unfortunately only gives length and breadth of the female.

Taylor's description of the parasite is rather inadequate, but the figures show that it has a typical Aphelenchid structure. The female is slightly longer than the male, and the anterior end in both sexes is somewhat swollen, thus resembling *A. ritzema-bosi*, whilst the tail in each case bears a small terminal process. The stylet and œsophageal bulb are normal in position and appearance. The post-bulbar region of the œsophagus is not figured in detail, but this is not surprising, as this part of the body is extremely difficult to make out.

The female reproductive organs are typical, consisting of ovary, uterus, pre- and post-vulvar vaginæ. The male reproductive organs are of the usual type, as are also the spicules. The restricted forward extension of the male gonad is noted by the author, and is clearly figured.

It is evident from a perusal of the paper that the author was not aware of the usual technic for the manipulation and preparation of small nematodes. Nor, apparently, was she conversant with the literature dealing with the plant parasitic forms, as no references are given to papers dealing with the subject. The inadequacy of her description is thus easily accounted for.

Some of her material was sent to Ritzema-Bos and to Dr. de Man, who both concluded that the worm belonged to the genus Aphelenchus; in spite of this, however, she referred it to the genus Tylenchus.

A re-examination of the parasite is much needed before its systematic position can be definitely determined. For the present it seems advisable to transfer it to the genus Aphelenchus with the specific name *ribes*. In size it comes nearest *A. ritzema-bosi*, and in the somewhat swollen character of the head end it resembles this species. The present writer sought, about three years ago, to get into touch with Miss Taylor, but

she had left the School of Agriculture, Cambridge, where the work had been carried out. It is unfortunate, also, that no preserved material could be found which would have facilitated a re-examination and further description of the worm.

Symptoms.—The species is parasitic on the buds of black-currant, *Ribes nigrum*, and is responsible for a considerable amount of destruction to bud tissue in the Cambridge district. It is an ectoparasite, and does not enter the tissues of the scale leaves and true leaves of the bud, but acts from the outside. It may either attack the protective scale leaves or distribute itself throughout the entire bud. In the former case the worms collect at the succulent area at the base of the scale leaves, and by causing a disruption of this bring about the death of the bud. Decay of the tissues furnishes a suitable medium for the multiplication of the worms. In the other case the parasites attack the true leaf tissues lying between the raised oil-glands which occur in the buds of black currant ; the glands themselves do not appear to be attacked. Associated with the attack, and characteristic of it, is an excess of moisture in the buds, particularly in the terminal ones, which is due to an exudation of sap from the injured tissues. Destruction of buds goes on most rapidly in Spring, but continues throughout the year.

Biology.—A number of observations were made and numerous experiments were carried out on the habits of the worm. It was found that when the moisture content of the atmosphere is such that surface films of water are deposited on the stem and buds, as would naturally occur in light rain or mist, the nematodes migrate up and down the stem and gain access to unaffected buds.

They do not wander on dry stems. Taylor describes the formation of colonies of worms in well attacked buds. Hundreds of worms in all stages of development are found towards the bases of the bud leaves aggregated into small white cotton-wool-like masses. These can be lifted entire, and when transferred to water the individual worms take on active movement. Such colonies are capable also of withstanding desiccation, for affected buds containing them can be gradually dried with the result that the worms coil up within the bud, and when the colonies are transferred to water the worms uncoil and resume active motility. A few can withstand drying for 9 months ; about 70 per cent. can be revived after drying for 6 months, the worms becoming active

in 1–2 hours. This habit of colony formation with coiling on desiccation recall the similar behaviour of *Tylenchus dipsaci* attacking narcissus bulbs (c.f. Goodey, 1923).

It would seem possible from the above results on desiccation that the disease might be spread by the dissemination of dried infected bud material by the wind or by mechanical agencies.

Experiments were conducted to determine whether the worms could infect other cultivated plants, and it was found that they would not attack strawberries, from which the conclusion was drawn that the parasite is not identical with *A. fragariæ*. On the other hand, it was ascertained experimentally that the worms could attack the expanding leaves of both red currant and gooseberry buds, but could not penetrate between the true leaves of the dormant buds. Observations, however, in orchards affected with black currant eelworm failed to reveal the worms in the buds of red currant and gooseberry.

A. OLESISTUS Ritzema-Bos, 1893.

Principal measurements in mms. :—

Length of body, female		0.477–0.644
,, ,, ,,	male	0.434–0.518
Breadth of body	...	0.011
Length of stylet	...	0.006–0.009
,, ,, spicules	...	0.011–0.015 dorsal portions.
,, ,, ,,	...	0.008–0.009 ventral portion.

Proportions :—

Female $a = 41–55$, $\beta = 9–12$, $\gamma = 11–16$
Male $a = 36–43$, $\beta = 8–9$, $\gamma = 14–18$

The excretory pore is on a level with the nerve ring, and the general structure in both sexes is that given on p. 145.

Symptoms.—This species produces leaf-blotch in a number of different ferns belonging to different genera, Pteris, Asplenium and Adiantum. It also attacks begonias and cryripediums. The writer, about four years ago, carried out some work on leaf-blotch in *Asplenium bulbiferum*. In addition to the blotch, and what, in the opinion of the growers, was a more serious trouble, was the occurrence of imperfect fronds in the form of gaps in the chief lateral branches. It is possible that this may have been due to the worms either attacking the growing fronds in the bud or merely a secondary effect of the blotch disease. The condition is one that requires much further investigation.

In blotch disease the worms live in the mesophyll spaces of the leaf,

and probably, by the secretion of a toxin, bring about the destruction and discoloration of the cells which give rise to the blotches.

Biology.—Under suitable atmospheric conditions, *i.e.*, when the relative humidity is high and surface films of moisture are deposited, the worms wander on the surface of the leaves and leaf-stalks, and enter the leaves through stomata or through wounds. Soil becomes infected through the fall of diseased leaves on to it. The usual atmospheric conditions of greenhouses—warmth with plenty of moisture—are favourable to the spread of the disease.

A. OLESISTUS *var.* LONGICOLLIS Schwartz, 1911.

Principal measurements in mms. :—

Length of body, female	0.483–0.728	
,, ,, ,, male	0.525–0.637	
Breadth of body ...	0.014–0.015	
Length of stylet, female	0.008–0.009	
,, ,, ,, male	0.008–0.010	
,, ,, spicules ...	0.012–0.015	dorsal portions.
,, ,, ,, ...	0.009	ventral portion.

Proportions :—

Female. $\alpha = 32–52$, $\beta = 7–9$, $\gamma = 13–18$
Male $\alpha = 37–45$, $\beta = 6–8$, $\gamma = 16–19$

This organism is similar in essentials to *A. olesistus ;* it differs from it, however, in having a longer œsophagus, and in having the excretory pore placed a little further back. Schwartz speaks also of the well-developed condition of the stylet and of the prominence of the trilobed bulb.

Symptoms.—It is pathogenic to cultivated violets in which, by attacking the bases of the leaf and flower stalks, it causes hypertrophy of the tissues, with consequent stunting and fasciation, and the final production of a massive gall in which the worms occur in abundance.

Biology.—Schwartz gives no account of the biology of this worm.

TREATMENT.

It is a fact well-known to helminthologists that nematodes are easily killed by heat. Acting on this knowledge the writer, when working with *A. olesistus* in diseased ferns, carried out some experiments to determine the temperature at which these worms are killed. It was found that 10 minutes at a temperature of about 45° C. was lethal to worms in water, and it seemed that it would be possible to treat affected plants

by immersion in warm water at about this temperature for a short time. On studying the literature, however, dealing with Aphelenchus it was found that Marcinowski (1909) had put forward the same method, and had suggested the immersion of affected plants in water at 50°–52° C. for 5 minutes as a means of destroying the parasites without injury to the plant.

The complete success attained by Ramsbottom (1920) in the warm water treatment of narcissus bulbs attacked by *Tylenchus dipsaci* and the similarly efficacious treatment, worked out by Byars (1920), for wheat contaminated with galls due to *Tylenchus tritici* by a warm water process, after previous soaking of the wheat in water, indicate the line along which the treatment of Aphelenchus diseases should proceed, *i.e.*, by heat treatment. In the case of the smaller greenhouse-grown pot plants the immersion of the whole plant in water for 5 minutes at about 50° C. could be carried out fairly easily. This, coupled with precautions to ensure the use of uninfected potting composts, would probably eradicate diseases due to Aphelenchus in chrysanthemums, ferns, begonias, etc. In the case of the diseases in violets, strawberry, black currant and coco-nut palm the problem of treatment is by no means so simple, but it seems to the writer that in these cases also a heat treatment could be applied.

Starting from the fact that infection of plants takes place from infected soil by migration of the worms on to them, the problem resolves itself into the provision of a method of heat treatment of soil which will destroy the parasites, coupled with restocking with clean plants from an uninfected source.

The work of Russell and Hutchinson and others on the partial sterilisation of soil by heat has shown that the process can be applied to greenhouse soils, but the method has, so far, not been used for field soils on a practicable scale. A few years ago, however, Guiness and Richards devised a machine which would carry out the heat treatment of field soils. In essentials this consisted of a plough for lifting the soil in connection with a suitable apparatus for submitting the broken-up soil to heat in a revolving drum, the soil being dropped after treatment. This mechanism reached a well-advanced experimental stage, and was shown to be capable of the partial sterilisation of soil in the field, but it has never been completed and put on the market.

It has seemed to the writer for a long time, however, that such a machine, if run efficiently and economically, would definitely clear up the diseases of plants due to parasitic nematodes by the destruction of the resting stages, adults, larvæ or eggs of the worms in the surface layers of the soil. It could be applied to strawberry fields for the eradication of " bunch " and " red-plant " disease, and for the treatment of soil infective for black currant eelworm, after first clearing the land of diseased stock. In the case of another nematode disease, *i.e.*, " bloaty " onion, caused by *Tylenchus dipsaci*, and still common in parts of Bedfordshire and Cambridgeshire, the application of the method would be simpler for the crop only occupies the land for a limited time, and the treatment could be applied in autumn or at another convenient time.

It might be possible to work the method in the case of " red-ring " disease of coco-nut palm, but here, possibly, special local conditions might obtain which would render modifications of the process necessary.

Even if the mechanical method of heat treatment suggested above could not be successfully employed owing to economic or other reasons, recourse might be had to the old method of " paring and burning." In any case some efficient method of heat treatment is, in the writer's opinion, indicated for these diseases, especially as the parasites are killed at comparatively low temperatures, such temperatures, in fact, as are attainable by the combustion of relatively small quantities of valuable fuel-stuffs. In the case of the strawberry diseases the need for a remedy is urgent already, as, unless such can be found, growers may find it necessary to abandon the cultivation of strawberries entirely.

Summary.

1. The paper deals with nematodes of the genus Aphelenchus causing diseases in cultivated plants. A list of these, with the main pathological conditions to which they give rise, is set out on page 144.

2. Each parasite and the disease due to it is dealt with, and particulars are given concerning the structure of the worm, together with the symptoms and biology in each case.

3. A general discussion on the problem of the appropriate treatment of these diseases is given, and the suggestion is made that some form of heat treatment of infective soils is likely to give the best results, owing to the fact that comparatively low temperatures are lethal to the parasites.

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On the Morphology of *Ollulanus tricuspis* Leuckart, 1865, a Nematode Parasite of the Cat.

By T. W. M. Cameron, M.A., B.Sc., Ph.D., M.R.C.V.S.

Introduction.

In 1865 Leuckart described from the Cat, in Germany, a very minute Strongyle worm which he called *Ollulanus tricuspis*. This worm which was recorded from Britain by Cobbold (1873) and Stirling (1877), but was not properly described or figured, has occurred recently in some cats examined by the writer.

Ollulanus tricuspis Leuck., 1865.
Syn. *Olulanus tricuspis* Cobbold, 1873.

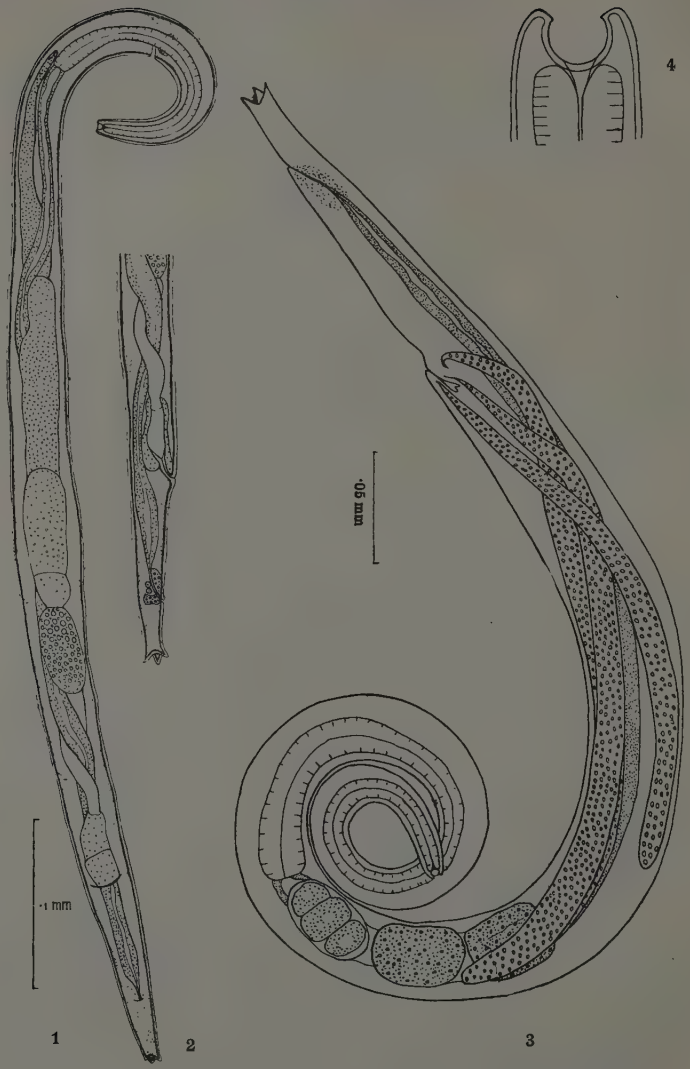
In the fresh state the parasites are colourless, and are generally found with the head end coiled on itself. They are very minute, the male measuring only .7 to .8 mm. in length, with an average breadth of .035 mm.; while the female is .8 to 1 mm. long, and about .04 mm. broad.

The cuticle is faintly striated transversely and more conspicuously striated longitudinally.

The Anterior Extremity.—A small buccal cavity is present containing no teeth, cutting plates, or similar structures. The cavity is formed by a reflection of the cuticle, and in optical section is almost spherical (Fig. 4). The lateral diameter is .004 mm., and its antero-posterior diameter is .005 mm.

The œsophagus, which is about .2 mm. long, is only slightly swollen posteriorly. The œsophageal muscles are poorly developed. The excretory pore is comparatively large, and is situated in the posterior œsophageal region, which it divides in the ratio of three to two. The cervical papillæ are large and posteriorly directed. They are just anterior to the excretory pore. The nerve ring is at the same level.

The Female.—The vulva (Fig. 2) is a prominent structure situated in



Ollulanus tricuspis: Fig. 1, Immature female, ventral aspect. Fig. 2, lateral view of tail of female. Fig. 3, Gravid female. Fig. 4, Oral capsule (enlarged).

the posterior region of the body, which it divides in the ratio of approximately five to one.

The vulva opens into a short vagina, which is continued anteriorly as a single uterus. The junction of uterus and vagina is surrounded by a granular mass in the immature female. This disappears in the mature female. There is no ovejector. The single ovary originates about the level of the œsophageal bulb, and insensibly joins the uterus. The ova are very large and granular. As the worm becomes older, the ovary becomes confined to the anterior part of the body, the remainder of which is occupied by the intestine and one to three very large larvæ (.3 to .35 mm. long). The anus is situated about .03 to .04 mm. from the

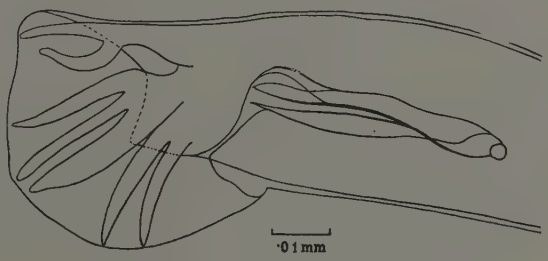


Fig. 5, *Ollulanus tricuspis*: Bursa, lateral view.

posterior end. The rectum is a straight tube about .015 mm. long.

The tip of the tail has typically three "cusps" or teeth; but occasionally one or two small extra cusps are found. (Fig. 6,c.)

The Male.—prebursal papillæ are absent. The bursa (Fig. 5) is undivided, and is open only on the ventral side. The dorsal ray is comparatively stout, and bifurcates near its tip. The externo-dorsal rays leave the dorsal ray about half-way down its main stem. They arise at right angles to the dorsal, but immediately bend posteriorly and terminate close to the digitations of the dorsal ray. (Fig. 6,a.)

The lateral group of rays originate together, the externo-lateral being the thickest. The postero-lateral ray has a conspicuous shoulder near its point of origin and is slightly shorter than the others.

The ventral rays are both about the same size and length, and both diverge from the lateral group.

The genital cone is of medium proportions, and is simple, with a single sharp point. The cloacal aperture opens about half-way down its ventral face.

The spicules are equal in length (about .05 mm.) and are bifurcated, one bifurcation being sharp and the other rounded. (Fig. 6, b.) There is no accessory piece.

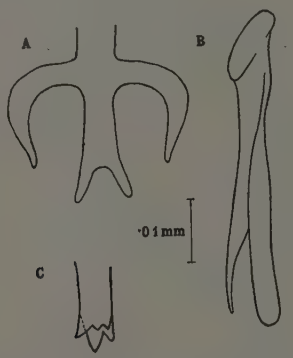


Fig. 6. *Ollulanus tricuspis*: (*a*) Dorsal ray of bursa; (*b*) Spicule; (*c*) tip of female tail.

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Necator americanus and the Domestic Pig.

By T. Goodey, D.Sc.

Introduction.

The occurrence of Ankylostomes resembling human hookworms in the domestic pig has been the subject of several recent papers, the most noteworthy being the contributions of Ackert and Payne (1922 and 1923) and Gordon (1922 and 1923).

Gordon (1922) records the finding of Ankylostomes in pigs in Amazonas, S. America, resembling *N. americanus* in all respects. He also deals briefly with the findings of other workers, except Ackert and Payne, and mentions that Maplestone showed him four Ankylostomes taken from a pig at Townsville, Australia ; three being *A. duodenale* and one exactly resembling *N. americanus*. Reference is also made to O'Connor (1920) and Legg and Rheuben (1921) who claim to have found *A. duodenale* in pigs, the former at Funafuti, Ellice Island and the latter in the region of Townsville, Australia.

Ackert and Payne (1922 and 1923) discovered that a large percentage of the domestic pigs in Trinidad, British West Indies, are infected with hookworms closely resembling *N. americanus* but, as they maintain, differing from this species in a number of points, and they consequently create a new species, *N. suillus*. They were unsuccessful in several attempts to infect young pigs with larvæ of *N. americanus*.

Gordon (1923) has examined the points of difference between *N. americanus* and *N. suillus*, set out by Ackert and Payne, and maintains that these are not constant and do not justify the separation of these worms into two species. He has also attempted to infect a young pig by subcutaneous inoculation of ensheathed larvæ of *N. americanus* since returning to England. The result of his experiment is, however, somewhat inconclusive, as although eggs indistinguishable from Necator eggs were found,

scantily in the animal's droppings about five weeks after inoculation, no worms were found in the intestine at the autopsy. It is uncertain, therefore, whether an infection had been set up and whether the eggs found were those of *N. americanus*.

The present position is briefly as follows :—Domestic pigs in Australia, S. America and Trinidad have been found harbouring Ankylostomes both *A. duodenale* and Necators ; *N. suillus* according to Ackert and Payne ; *N. americanus* according to Gordon. Infection experiments on pigs have so far proved inconclusive, for although Ackert and Payne claim that *N. americanus* will not grow in pigs, yet, as Gordon points out, all their experimental animals contained Necators when killed. These the American workers call *N. suillus*, whilst Gordon considers them to be *N. americanus*. Gordon's own attempt to infect a pig is also inconclusive inasmuch as no *N. americanus* was found in the intestine.

At the suggestion of Prof. R. T. Leiper it was decided to attempt an infection of the pig with human ankylostomes. *N. americanus* does not occur normally in any part of England, and it was safe to assume therefore that pigs obtained at an open market in the vincinty of London would not be carrying this parasite, and further that any of these worms found in an animal after an attempt to infect it with larvæ from a known human infection would be a positive result. Two pigs were purchased in St. Albans market and were kept during the course of the experiment at the farm of the Rothamsted Experimental Station, Harpenden. We are indebted to Sir John Russell, Director of Rothamsted Experimental Station and to Mr. S. J. K. Eames, Farm Manager, for facilities for keeping the pigs at Rothamsted Farm. The hookworm larvæ used were cultured from fæces of patients in the Hospital for Tropical Diseases.

Experimental.

The two pigs were about 12 weeks old when obtained. On 8/5/23 400-500 ensheathed larvæ of *N. americanus* were applied to the soft skin of the groin of the smaller pig in a thin paste of fæcal matter from the cultures in which the larvæ had been reared. The pig was held in position for 50 minutes until the paste had dried on to the skin. These larvæ were known to be capable of skin penetration, as a sample of them

had been tested the day previous by the writer's floating cork and skin method (Goodey 1922) and were found to leave their sheaths and enter the skin. It was assumed, therefore, that they would infect through the soft skin of the pig's groin.

On 23/6/23 the same pig and its fellow were given a very large dose, about 200,000 in all, of ensheathed hookworm larvæ. As the pigs were now too much grown for skin infection these larvæ were fed to them by the mouth in a small quantity of liquid food and means were taken to ensure that each pig had an equal share of the infective mixture. Before being given this feed the pigs had been kept fasting for about 8 hours.

On 20/7/23, that is, $2\frac{1}{2}$ months after the application of the larvæ to the skin and 1 month after feeding with larvæ, the first pig was killed and a thorough search made of the alimentary tract for the presence of adult or growing *N. americanus* but not one was found. The contents of the small intestine were run out and washed through two sieves and the whole of this material, sievings and washings, was examined in small quantities in a shallow glass dish over a dark ground so as to show up small white bodies. The small intestine was opened and the surface gently scraped and carefully examined inch by inch but with entirely negative result. The same procedure was adopted for the contents of the cæcum and large intestine and the walls were scrupulously examined but no sign of *N. americanus* was found. One small worm was obtained from the cæcal contents and this proved to be an immature specimen of *Œsophagostomum dentatum*.

The second pig was killed on 1/8/23, that is, 5 weeks and 3 days after receiving its feed of hookworm larvæ and the same procedure was adopted as before for the examination of the contents of the whole intestine and of the walls of each part. The result again proved entirely negative for *N. americanus* ; neither adults nor growing forms were found. About 50 specimens of *Œsophagostomum dentatum* however, mostly mature forms, were recovered from the sievings of the cæcum and large intestine.

Before the pigs were killed, eggs of a nematode parasite were found in the droppings of each and were fairly abundant in those of the second one to be killed. These eggs measured 0.07-0.074 mm. in length by 0.04-0.041 mm. in breadth and the contents were in a well advanced stage of segmentation. On first finding them it was thought that they

might possibly be the eggs of *N. americanus* though their large size and the condition of the contents were against this view. Gordon (1923) says that the eggs found in the droppings of his pig measured 0.068 mm. in length by 0.037 mm. in breadth and were indistinguishable from those of *N. americanus*. In view of the fact, however, that he failed to obtain adult worms of this parasite at the post-mortem examination of the pig it is permissible to surmise that the animal may have been carrying a natural infection of *Œsophagostomum dentatum* whose eggs were mistaken for those of *N. americanus*. It is to be noted, however, that the droppings of the animal were free from nematode eggs before the inoculation with larvæ of *N. americanus* was carried out.

The writer's attempts to infect pigs with larvæ of *N. americanus* both by skin penetration and by the mouth have proved entirely negative.

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Journal of Helminthology, 1923. *Vol.* I., *pp.* 165-189.

Observations on the Nematode Genera *Kalicephalus*, *Diaphanocephalus*, and *Occipitodontus* g.n., and on the Larval Development of *Kalicephalus philodryadus* sp.n.

By R. J. Ortlepp, M.A., Ph.D., F.Z.S.

Introduction.

The following communication is based mainly on material collected at the Prosectorium of the Zoological Society of London. In it there is also incorporated a study of several species in the collection of the Helminthological Department of the London School of Tropical Medicine.

An attempt is here made to re-describe the type species of *Diaphanocephalus*, and as a result it is shown that its separation from the genus *Kalicephalus* by Molin is justified. In addition, five known and six new species of the genus *Kalicephalus* are dealt with. Of the latter two are from Southern Africa, one from India, two from North America and one from South America. A new genus, *Occipitodontus*, is created for the reception of an allied parasite from the Banded Krait, which the writer considers to have been hitherto wrongly included in v. Linstow's species *Kalicephalus willeyi*, originally described from *Vipera russelli* and *Coluber helena*.

Molin, who created the genus *Kalicephalus* (1861) included in it seven new species from South America. According to present day standards, and also because the members of this genus are so closely related, Molin's descriptions are quite inadequate for the specific determination of his species. In consequence of this all specimens from America are treated as new species, except those obtained from hosts from which Molin described his species. Should a re-examination of Molin's types show that some or all of these have already been named, then it is quite a simple matter to relegate them to synonyms. The writer feels that it is better to have several synonyms for one parasite than that several different worms should later be found to have been confused together under the same name.

The members of the genus *Kalicephalus* fall naturally into two groups, according as their uteri are convergent or divergent. This character, which has been found constant in all the specimens examined, is regarded as at least of specific significance. The generic diagnosis for *Kalicephalus* has now to be amended so as to read " Two uteri divergent or convergent."

Genus DIAPHANOCEPHALUS Diesing, 1851.

DIAPHANOCEPHALUS GALEATUS (Rudolphi, 1819), Railliet & Henry, 1909.

Syns. *Strongylus galeatus* Rud., 1819.
Sclerostomum galeatum (Rud., 1819) Duj., 1845.
Diaphanocephalus strongyloides Dies., 1851.

Host. *Podinema teguexin.*

Locality. Brazil.

Habitat. Intestine.

One entire male and one female and several portions of each were available for study. Unfortunately their state of preservation was so poor that it was not possible to determine their internal characters; sufficient characters were, however, made out to warrant a re-description, notwithstanding the fact that no mature female was available for study.

The entire female is 3.7 mm. long and .26 mm. broad, and the male is 4.13 mm. long with a maximum breadth of .25 mm. In the female the body has a uniform thickness, except that portion of it posterior to the vulva; this portion is sharply set off from the rest of the body, and is about three-quarters of the body thickness immediately anterior of the vulva. In the male the body thickness is more or less the same throughout.

The head is marked off from the rest of the body by a slight constriction. It is laterally compressed, and is supported by two cuticular valves, each possessing a very much thickened base. On the inner surface of each valve there are two ledges projecting inwards; one on the anterior limit of each valve and running parallel with its edge, and the other a short distance posterior to the first. When viewed laterally this latter ledge has the shape of an arc, but when viewed from either the dorsal or ventral aspect they together form a broad V. The terminations of each posterior ledge rest on a thickened cuticular pad situated between

the junctions of the buccal valves. From the ventral cuticular pad two membranous cuticular processes project upwards into the mouth cavity. The function of these processes is not clear ; at any rate, they are much too delicate to be able to function as teeth. The margin of the mouth is bounded by a thin membrane projecting forwards and showing traces of longitudinal striations (corona radiata ?). The anterior face of the head is obliquely truncated, in consequence of which the buccal capsule is deeper on its ventral than on its dorsal side, and the mouth thus appears to be tilted slightly towards the dorsal aspect.

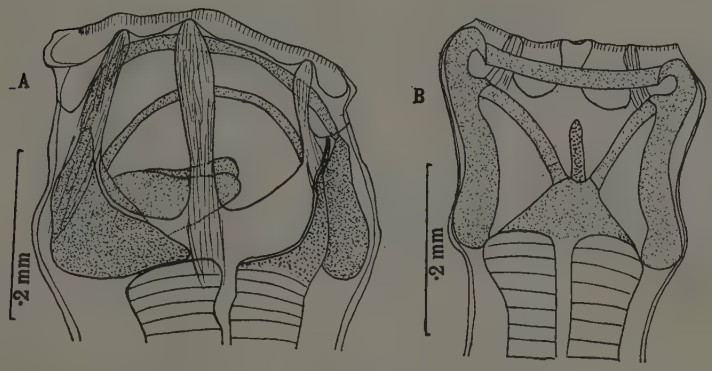

Fig. 1. *Diaphanocephalus galeatus.* (*a*) cephalic end, female lateral view. (*b*) cephalic end, male, lateral view (mouth open ..

On the outer surface of each valve there are three parenchymatous bands arising from a basal collar ; their tips terminate as small papillæ round the mouth. The duct of the œsophageal gland is well developed, and projects into the buccal cavity for nearly two-thirds of its length.

Female.—In the entire female the vulva is situated .875 mm. from the posterior extremity, its position thus dividing the body into the ratio of 3.2 : 1. The body contents were too macerated to make out the internal genitalia, but from the position of the vulva it is probable that the uteri are parallel. The tail is short and pointed, and measures .11 mm. long.

Male.—The bursa is short and campanulate, its depth being about the same on its dorsal and ventral aspects. There is only a very slight trace of a dorsal lobe. The dorsal ray is short and thick, and very soon gives origin to the externo-dorsal rays, which in a graceful curve pass almost to the edge of the bursa. The bifurcation of the dorsal ray takes place immediately posterior to the origin of the externo-dorsals. Each of its branches immediately divides into two, namely, a thick inner branch which becomes deeply notched at its tip, and a slightly slenderer and elbowed outer branch. The lateral rays arise from a common trunk, the postero-lateral soon separating from the other two laterals and running parallel with the externo-dorsal. The medio- and externo- laterals run parallel to each other for about half their length, after which they diverge

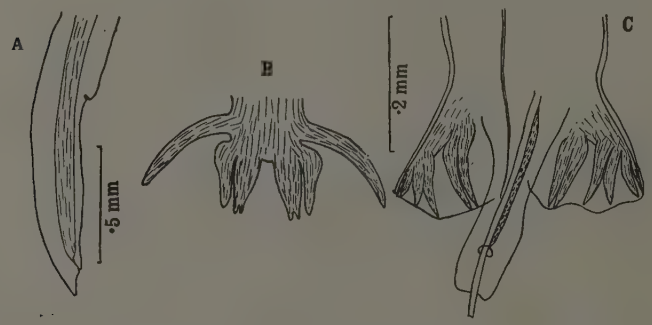

Fig. 2. *Diaphanocephalus galeatus.* (*a*) tail of female.
(*b*) Dorsal ray of bursa.
(*c*) Bursa, ventral view.

slightly. The ventral rays are long and parallel. All the rays extend almost to the edge of the bursa.

The genital cone is very well developed and protrudes some considerable distance out of the bursa. In the entire male it was nearly .3 mm. long and .09 mm. thick at its base; its tip is slightly notched. The ano-genital aperture is situated on its ventral surface about .08 mm. from its tip.

Two spicules and a gubernaculum are present. Unfortunately the right spicule is broken. The left spicule is .66 mm. long by .11 mm. thick at its base; it tapers gradually to a filiform point. The right

spicule has the same basal thickness as the left, but the remaining portion of it is relatively thicker than the corresponding portion of the left spicule. The gubernaculum is boat-shaped and elongate, and measures .215 mm. long.

The dorsal hump anterior to the bursa mentioned by Molin is present.

Railliet and Henry (1909) suppressed the genus *Kalicephalus* Molin, 1861, as they considered it to be synonymous with the genus *Diaphanocephalus* Diesing, 1851. Later workers on this group have adopted this view. From a re-examination of specimens of the type species of the genus *Diaphanocephalus*, the differences between it and the members of the genus *Kalicephalus* appear to the writer to be sufficient to warrant the retention of Molin's genus. The genus *Diaphanocephalus* would thus differ from the genus *Kalicephalus* by (1) the presence of two cuticular ridges on the inner surface of each buccal valve; (2) the presence of two cuticular projections into the mouth cavity; (3) the campanulate nature of the bursa; (4) the very short and stout dorsal ray; (5) the very elongate genital cone; and (6) the position of the ano-genital aperture on the ventral side and some distance behind the tip of the genital cone.

Genus OCCIPITODONTUS, Gen. nov.

OCCIPITODONTUS FIMBRIATUS nom. nov., t. sp.

Syns. *Kalicephalus willeyi* v. Linstow, 1908 (not 1904).
Diaphanocephalus willeyi (v. Linst.), Baylis & Daubney, 1922.
Diaphanocephalus willeyi (v. Linst.), Daubney, 1923.

Host. *Bungarus fasciatus*.

Locality. India.

Habitat. Stomach and duodenum.

Examples of this parasite were collected on two occasions from the Banded Kraits which died in the Gardens of the Zoological Society of London.

The interest in this parasite lies in the fact that it possesses a distinct corona radiata as first noted by Baylis and Daubney; and also that there are three pointed teeth projecting forwards from a shallow œsophageal funnel. These are situated one dorsal and two ventro-lateral in position; they are about .04 mm. high.

The male genital bursa agrees with Daubney's description, except that the postero- and medio- lateral rays are not closely applied to each other. The genital cone is also slightly smaller, measuring .07 mm. long by .078 mm. broad at its base.

The presence of a corona radiata and of œsophageal teeth appear to the writer to be of sufficient importance to warrant the creation of a new genus for the reception of this species.

Types to be deposited in the British Museum (Natural History).

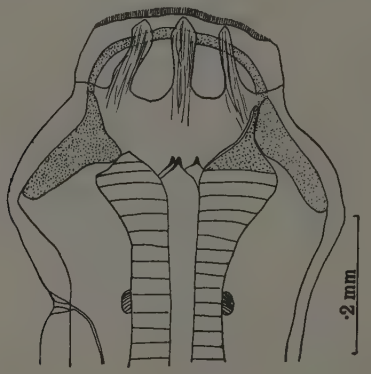

Fig. 3. *Occipitodontus fimbriatus*. Cephalic end, lateral view, shewing œsophageal teeth.

Genus KALICEPHALUS Molin, 1861.

Syns. *Diaphanocephalus* Railliet & Henry, 1909 (in part).
Sclerostomum Dujardin, 1845 (in part).

GROUP A. (UTERI DIVERGENT.)

KALICEPHALUS WILLEYI v. Linstow, 1904.

Not *Kalicephalus willeyi* v. Linstow, 1908.

,, *Diaphanocephalus willeyi* (v. Linst.), Baylis & Daubney, 1922.

,, *Diaphanocephalus willeyi* (v. Linst.), Daubney, 1923.

Syn. *Diaphanocephalus* sp., Bayl. & Daub., 1922, from *Vipera russelli*.

Host. *Vipera russelli*.

Locality. India.

Habitat. Stomach and duodenum.

The material examined consisted of three tubes of specimens all collected

from the Russell's viper. Only females were present. Baylis and Daubney (1922) have given a full description of the female.

v. Linstow described this species from specimens obtained from *Vipera russelli* and *Coluber helena*. Later he recorded that he had found the same species from *Bungarus fasciatus*. His description is so general and his figures so diagrammatic that it is almost impossible to identify his species from his data. In his first communication v. Linstow states that his specimens consisted of numerous females with only one male. From this it would appear that his specimens are identical with the writer's three lots, and with the nine lots examined by Baylis and Daubney from the same host (Russell's viper). In all cases only females were present. The males would thus appear to be very rare. With regard to the data given by v. Linstow for the female, the size agrees with the writer's specimens. A noticeable difference, however, is the position of the vulva; v. Linstow gives its position as dividing the body into the ratio of 18 : 5, *i.e.*, 3.6 : 1, whereas in the writer's specimens this ratio is about 1.6 : 1, and in Baylis and Daubney's specimens about 1.5 : 1. In the species from *Bungarus fasciatus* this ratio also does not agree with v. Linstow's findings, in that the ratio in the writer's specimens is about 1.8 : 1 (10.5 : 5, *i.e.*, 2.1 : 1 in Daubney's). We are, therefore, led to conclude either that the writer's and Baylis and Daubney's specimens from *Bungarus fasciatus* and *Vipera russelli* are not the same as v. Linstow's specimens, or that v. Linstow's observation with regard to the position of the vulva was incorrect. As the Russell's viper is the first host mentioned by v. Linstow, we can regard this ophidian as the trophotype (type host), and can, therefore, assume that the species collected from it will most probably be identical with that described by v. Linstow. That this is a legitmate assumption is further supported by the fact that on twelve subsequent and different occasions identical specimens, and these only, have been collected from the Russell's viper.

The specimens from *Bungarus fasciatus* examined by the writer are all different from those obtained from the Russell's viper. It is thus almost certain that v. Linstow's identification of his specimens from the former host as *K. willeyi* is incorrect, especially when we take into account the fact that both are about the same size, and can thus easily be mistaken the one for the other.

KALICEPHALUS MINUTUS (Baylis & Daubney, 1922).

Syn. *Diaphanocephalus minutus* Baylis & Daubney, 1922.

This species was originally described from *Naja tripudians*, India. The writer has since also obtained it from the Banded Krait, *Bungarus fasciatus*.

The chief distinguishing characters of this small species are (1) the shape of the dorsal bursal ray which has two main terminal branches instead of the usual four, (2) the fact that the ventral bursal rays are fused together for about two-thirds of their length, and (3) the presence of well defined pre-bursal papillæ in the male.

KALICEPHALUS COLUBRI sp.n.

Host. "Colubrine Snake."

Locality. East Africa.

Habitat. ? Duodenum.

This is a slender species, the males not exceeding 6 mm. in length with a maximum thickness of .25 mm., and the females 7 mm. by .27 mm. thick. In the female the body has a more or less uniform thickness in its anterior three-fifths, the posterior two-fifths being slightly attenuated. In the male the body is only slightly attenuated in its posterior half.

The head is slightly flattened laterally and is not set off from the rest of the body. In lateral view its anterior edge is rounded and the mouth faces directly forwards. In the largest female the head has a dorso-ventral diameter of .21 mm. and a lateral thickness of .19 mm. The three parenchymatous bands to each buccal valve are nearly straight, the median being slightly thicker than the laterals. All terminate in small papillæ round the mouth. The mouth cavity is oval in dorso-ventral optical section, and has a depth, up to the level of the œsophagus, of .135 mm. In optical section the thickened base of each valve is shaped somewhat like a foot. The duct of the œsophageal gland extends more than half the distance into the buccal cavity, and is about .08 mm. long.

The œsophagus in the largest female is .33 mm. long, and in the largest male .314 mm. The nerve ring encircles it at its narrowest part, *i.e.*,

just in front of its middle. The excretory pore is very faintly indicated, and is situated on the same level as the cervical papillæ, *i.e.*, opposite the middle of the œsophageal bulb.

Female.—The tail, which is .33 mm. long, tapers gradually to a rounded point. The vulva is only very slightly raised, and its position divides the body roughly into the ratio of 2.2 : 1. A short vagina leads into

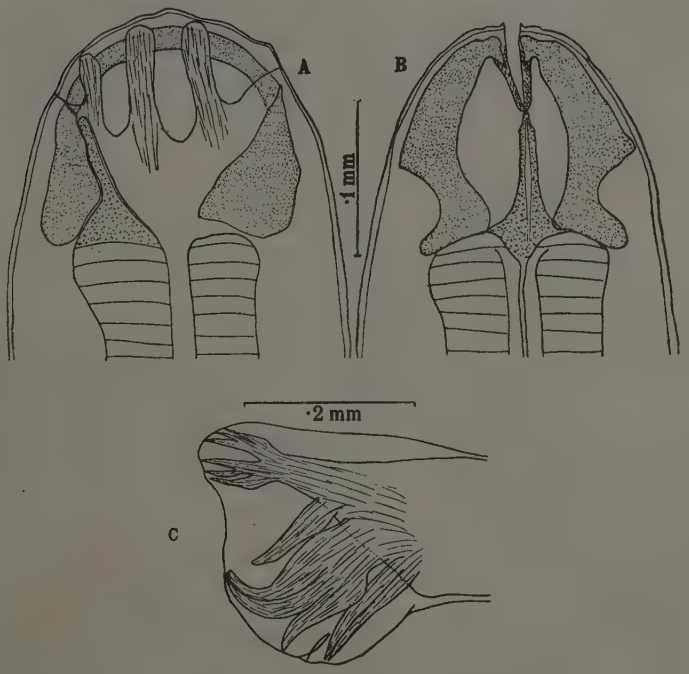

Fig. 4. *Kalicephalus colubri.* (*a*) Cephalic end, female, lateral view. (*b*) Cephalic end, female, dorsal view. (*c*) Bursa.

the opposed ovejectors, each of which joins one of the divergent uteri. The eggs are oval, thin-shelled and segmented *in utero* ; their average measurements are .055 mm. long by .039 mm. broad.

Male.—The genital bursa is distinctly trilobed, and in lateral view appears to be only slightly truncated obliquely. The dorsal ray is relatively short, and gives rise to the externo-dorsals near its origin.

It divides into two branches, each of which immediately divides, and the inner branches of these last are again divided for about half their length. The externo-dorsal is slightly curved and terminates some distance from the edge of the bursa. The lateral rays all originate from a common trunk, and are of more or less the same thickness ; the externo-lateral is, however, slightly shorter. The postero- and medio- laterals are closely applied to each other, and their posterior halves are bent dorsalwards. The anterior half of the externo-lateral is closely applied to the medio-lateral, but its posterior half diverges from it and is bent slightly ventralwards. The ventral rays are long and slender and closely applied to each other.

The genital cone is small and inconspicuous. The spicules are slender and alate, and both terminate in fine points. They are .34 mm. long by .01 mm. thick at their bases. A gubernaculum is present, but is very inconspicuous, being represented by a pale cuticular thickening dorsal to the spicular canal.

Types in the Helminthological Department of the London School of Tropical Medicine.

Kalicephalus obliquus (Daubney), 1923.

Syn. *Diaphanocephalus obliquus* Daubney, 1923.

Host. *Bitis gabonica.*

Locality. South Africa.

Habitat. ? Duodenum.

Several specimens of this parasite in good preservation were available for study. They, however, differ slightly from Daubney's description in that the genital cone of the male was found to be much longer and slenderer. Daubney gives its size as .07 mm. long by .09 mm. in maximum thickness ; in the writer's specimens the genital cone was very prominent, being as long as .18 mm. by .045 mm. broad in the larger specimens. No flattened process towards the base of the median parenchymatous band of the head was observed.

To this species there is tentatively referred some specimens from a colubrine snake, from Northern Nigeria. The females vary in length from 7.5 to 15 mm. with a maximum thickness of .55 mm., and the males are from 6 to 11 mm. long with a maximum thickness of .28 mm.

The specimens differ from those mentioned above in that there is no papilliform outgrowth on which the vulva opens, the vulva being situated merely on a thickened pad, and in that the genital cone is much shorter, being about .085 mm. long.

KALICEPHALUS SUBULATUS Molin, 1861.

Host. *Boa constrictor.*

Locality. South America.

Habitat. Stomach and intestine.

Numerous specimens of this species were collected on different occasions at the prosectorium of the Zoological Society of London. Molin first described it from *Lachesis rhombeata*, *Bothrops jararaca* and *Boa constrictor*. The first named snake is probably to be regarded as the trophotype.

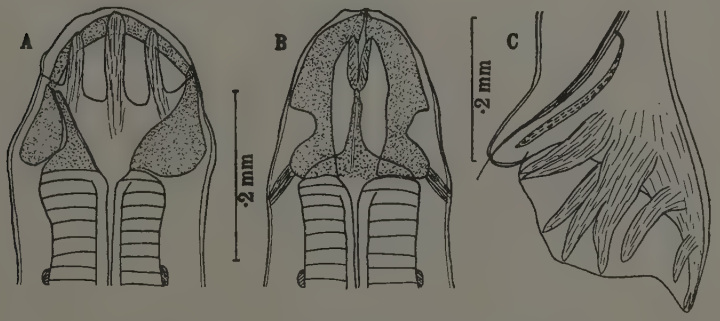

Fig. 5. *Kalicephalus subulatus.* (*a*) Cephalic end, male, lateral view. (*b*) Cephalic end, male, dorsal view. (*c*) Bursa.

This slender species has its males ranging in length from 6.5 to 8 mm., with a maximum thickness of about .3 mm., and the females vary from 7 to 9.5 mm. long with a maximum thickness of .43 mm.

The head is compressed laterally and is not definitely set off from the rest of the body. Its dorso-ventral diameter (male) is .24 mm. and its lateral diameter is .21 mm. The mouth points directly forwards and its anterior margin is rounded. The three parenchymatous bands of each valve terminate in small papillæ round the mouth; they are more or less straight, and the median is thicker than the laterals. The valves are about .2 mm. in height and are thickened at their base. From the

outer margin of this thickening a strong band of muscles is directed obliquely outwards and backwards. The duct of the œsophageal gland is about .11 mm. long and extends a little more than half way into the buccal cavity which, in optical section (dorso-ventral), is oval in shape.

The œsophagus is straight and thickened in its posterior two-thirds. In the male it is about .375 mm. long and in the female .445 mm. The nerve ring encircles it at about the junction of its first and second thirds. The excretory pore is faintly indicated and is situated about half way between the level of the nerve ring and the base of the œsophagus. The cervical papillæ are small and are found slightly posterior to the level of the excretory pore.

Female.—The body of the female is slightly attenuated towards the cephalic end, and in its posterior third it narrows gradually to end in a pointed tail about .363 mm. long. The vulva is slightly protuberant, but there is no papilliform outgrowth. It is situated in the posterior half of the body, and its position divides the body into the ratio of 2 : 1. A short vagina joins up with the divergent ovejectors whose combined length is about .37 mm. The uteri are opposed.

The eggs are oval and thin-shelled and vary in length from .062 to .07 mm. by .035 to .039 mm. in breadth. They are segmented *in utero*.

Male.—The body tapers slightly from the base of the œsophagus to the origin of the bursa. The bursa consists of a median and two lateral lobes. In lateral view it appears to be obliquely truncated. The bursal rays show no distinctive features. The genital cone is well developed and protudes obliquely outwards ; it is about .11 mm. long by .078 mm. broad at its base.

The spicules are relatively long, filiform, alate and irregularly bent ; they are over .5 mm. long and about .012 mm. thick at their base. A gubernaculum is present. It is a well cuticularised structure measuring about .2 mm. long by .026 mm. broad.

Kalicephalus coronellæ sp.n.

Host. Coronella triangulum.

Locality. North America.

Habitat. Stomach.

The males vary in length from 11 to 11.5 mm., with a thickness up to

.28 mm.; the females are from 19 to 20 mm. long with a maximum thickness of .35 mm.

The head is marked off from the rest of the body by a slight constriction, and is compressed from side to side. Its dorso-ventral diameter (male) at its base is .22 mm., and its maximum lateral diameter is .19 mm. Its anterior face is rounded and the parenchymatous bands are slightly bent, and terminate in small circumoral papillæ. The valves are about .15 mm. high, and their bases are thickened and project slightly outwards and backwards. The duct of the œsophageal gland extends about half way into the lumen of the buccal cavity.

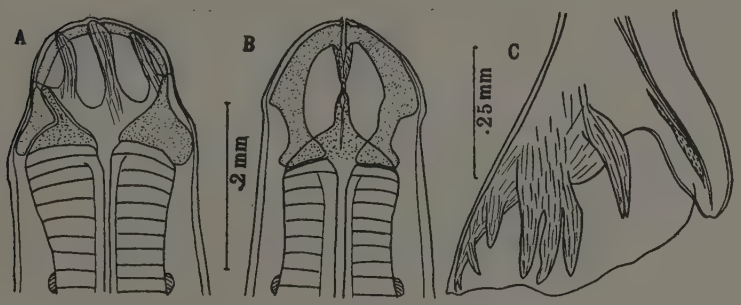

Fig. 6. *Kalicephalus coronellæ.* (*a*) Cephalic end, male; lateral view. (*b*) Cephalic end, male, dorsal view. (*c*) Bursa.

The œsophagus is .42 mm. long (male) with a maximum thickness of .24 mm., and the nerve ring encircles it at the junction of its second and third fifths. The excretory pore and cervical papillæ are on the same level, and are situated about half way between the level of the nerve ring and the base of the œsophagus.

Female.—The body is slightly attenuated anteriorly, and more so posterior to the vulva. The anus is situated about .6 mm. from the tip of tail, which tapers to a fine point. The vulva is situated on a very prominent papilliform outgrowth nearly .22 mm. long; in consequence of this the vagina is slightly elongate, measuring about .33 mm. long; its position divides the body roughly into the ratio of 1.66 : 1. The ovejectors, about .6 mm. in total length, and the uteri are opposed to each other directly.

The eggs are oval, thin-shelled and segmented *in utero*; they measure about .065 mm. long by .035 mm. broad.

Male.—The body of the male has a more or less uniform thickness, except for a slight thinning just anterior to the bursa and at the cephalic extremity. The bursa is trilobed and the median lobe is slightly notched. In lateral view it has a slightly obliquely truncated appearance. The bursal rays show no special peculiarities. The genital cone is prominent and measures about .2 mm. long.

The spicules are slender and taper to fine tips; they are alate and measure about .78 mm. long by .013 mm. thick at their bases. The gubernaculum is canoe-shaped and is narrower in its anterior third. It is just over .2 mm. long by .02 mm. broad in its posterior half.

Types to be deposited in the British Museum (Natural History).

Group B. (Uteri Convergent).

Kalicephalus simus (Daubney, 1923).

Syn. *Diaphanocephalus simus* Daubney, 1923.

Two tubes, containing several specimens, of this species from the Black Mamba (*Dendraspis angusticollis*) were examined. One lot came from Nyasaland and the other from the Congo.

Kalicephalus nigeriensis sp.n.

Host. "Snake."

Locality. Nigeria.

Habitat. ? Duodenum.

Four females and one male of this species were available for study. The females vary in length from 12 to 14 mm., with a maximum thickness of .495 mm., and the male is 7 mm. long and .264 mm. thick.

The head is large and laterally compressed, and its anterior face is rounded. The mouth points directly forwards. In the largest female the dorso-ventral diameter of the head is .42 mm., and its greatest lateral diameter .29 mm. The valves are .23 mm. high, and are slightly thickened at their bases. The parenchymatous bands terminate in small papillæ, and the median appears to possess a rounded one at its base. The duct of the œsophageal gland is about .11 mm. long.

The œsophagus in the largest female is .62 mm. long, and in the male .477 mm.; in the female the nerve ring is .23 mm. from its anterior end. The excretory pore is only seen with difficulty, and the cervical papillæ are very small; both are situated at the same level just posterior to that of the nerve ring.

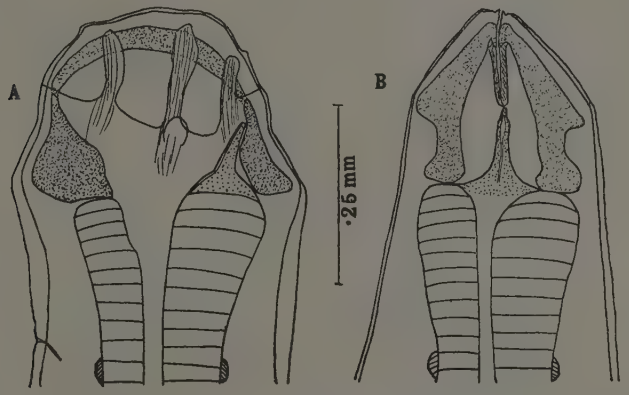

Fig. 7. *Kalicephalus nigeriensis.* (*a*) Cephalic end, female, lateral view. (*b*) Cephalic end, female, dorsal view.

Female.—The body in its anterior half has a uniform thickness except at its cephalic extremity, which is slightly thinner. Only a slight attenuation is evident in the posterior half of the body as far as the anus, after which there is a marked thinning terminating in a relatively slender tail about .41 mm. long. The vulva is slightly protuberant, and the vagina is very short. The ovejectors are directly opposed to each other, and measure together about .43 mm. long. The posterior uterus at first runs straight back, but it soon recurves and passes forwards parallel to the anterior uterus.

The eggs are oval, thin-shelled and morulate *in utero*; on an average they are .069 mm. long by .039 mm. broad.

Male.—The body of the solitary male is much slenderer than that of the female. It has a uniform thickness in its anterior half, and in its posterior half it is slightly attenuated to the base of the bursa. The bursa is trilobed, and appears obliquely truncated in lateral view. The

rays are more or less typical, except that the externo-lateral ray is much shorter and blunter than the other laterals. The genital cone is large, and is about .1 mm. long.

The spicules are typical for the genus, being filiform and alate. They are .37 mm. long with a thickness at their bases of .012 mm. A gubernaculum is present, which tapers towards its anterior extremity; it is .19 mm. long.

Types in the Helminthological Department of the London School of Tropical Medicine.

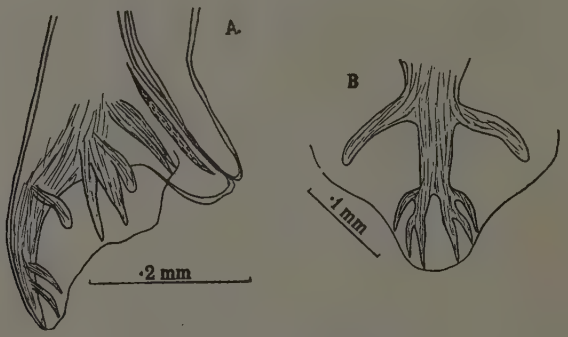

Fig. 8. *Kalicephalus nigeriensis*. (*a*) Bursa. (*b*) Dorsal ray of bursa.

Kalicephalus indicus sp.n.

Hosts. *Zamenis mucosus.* *Tropidonotus piscator.*

Locality. India.

Habitat. Stomach and duodenum.

This is a small species slightly larger than *K. minutus*, from which it can, however, be easily distinguished by its convergent uteri and the nature of the dorsal bursal ray in the male.

The females vary in length from 6.4 to 8 mm., with a maximum thickness of about .33 mm., and the males are from 5.1 to 6 mm. long by .27 mm. in maximum thickness.

The head is laterally compressed, with its anterior face slightly rounded, and pointing directly forwards. In lateral view it presents a slight shoulder-like bulging on either side towards its base. It is, however, not marked off from the rest of the body. In a male 6 mm. long the breadth across the shoulders was .17 mm., and its transverse thickness at the same level .14 mm. The parenchymatous bands are straight, and of about the same thickness; all terminate in small circum-oral papillæ. The buccal valves are .12 mm. high with thickened bases, which in dorso-ventral optical section appear foot-shaped. The buccal cavity which is from .125 to .15 mm. deep (male and female) is laterally

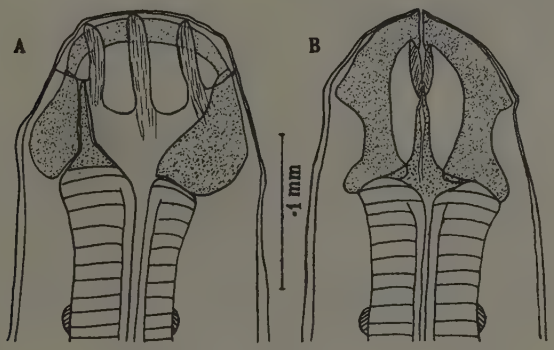

Fig. 9. *Kalicephalus indicus.* (*a*) Cephalic end, male, lateral view. (*b*) Cephalic end, male, dorsal view.

compressed, and in dorso-ventral optical section is somewhat egg-shaped, and in lateral optical section appears somewhat like an inverted triangle whose base is slightly bent outwards. The duct of the œsophageal gland extends barely more than half-way into the buccal cavity; on either side it is supported by the usual cuticular thickenings.

The œsophagus in the smallest male is .277 mm. long, and the nerve ring is situated .08 mm. from its anterior end. The cervical papillæ are small, and are found nearly .3 mm. from the cephalic extremity, *i.e.*, about midway between the level of the nerve ring and the base of the œsophagus. The excretory pore is very indistinct, and is situated just posterior of the level of the nerve ring.

Female.—The body is slightly attenuated in its anterior fifth. Behind this it maintains a uniform thickness up to the level of the vulva. The portion of the body posterior of the vulva narrows abruptly, and remains of the same thickness up to the anus, after which it tapers rapidly to form a pointed tail about .16 mm. long. The vulva is slightly raised, and its position divides the body into the ratio of about 3.4 : 1. The short vagina (about .05 mm. long) leads into the muscular ovejectors, which may either be directly opposed to each other, or the posterior ovejector may be obliquely inclined backwards and dorsalwards. In either case the posterior uterus immediately bends forwards and runs parallel to the anterior uterus.

The eggs are oval, thin-shelled and segmented *in utero* ; they measure from .055 to .065 mm. long by .027 to .33 mm. broad.

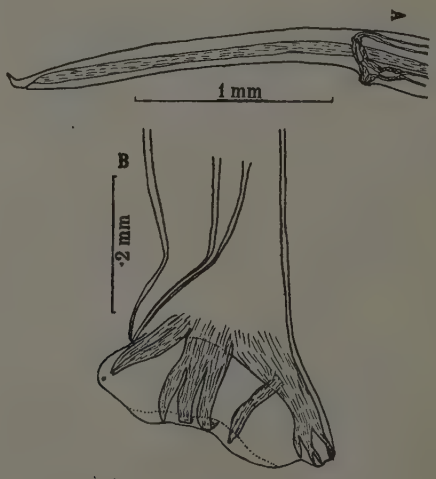

Fig. 10. *Kalicephalus indicus.* (*a*) Caudal end, female. (*b*) Bursa.

Male.—The body of the male has a uniform thickness throughout, except for a very short distance anterior of the bursa, which is slightly thinner. The bursa is trilobed, and the edges of the lateral lobes are incurved ; when these are spread out the bursa then appears somewhat campanulate in lateral view. The externo-dorsal ray originates from the

dorsal about half way between its base and its first bifurcation. The lateral rays diverge slightly from each other, and the externo-lateral is much shorter.

The spicules are equal, filiform and alate. They are about .39 mm. long with a basal thickness of about .011 mm. A gubernaculum is present but it is not distinct; it measures about .13 mm. long.

Types to be deposited in the British Museum (Natural History).

KALICEPHALUS PHILODRYADUS sp.n.

Host. *Philodryas serra.*

Locality. South America.

Habitat. Stomach, duodenum and intestine.

Numerous examples of this parasite were collected from a single Saw-marked Snake. All the males and some of the females were fixed in hot alcohol. The remaining females were allowed to deposit eggs in

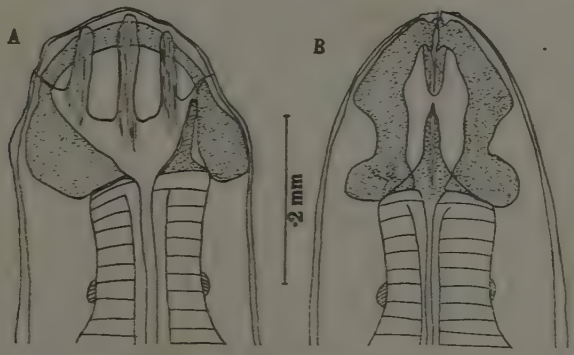

Fig. 11. *Kalicephalus philodryadus.* (a) Cephalic end, male, lateral view. (b) Cephalic end, male, dorsal view.

normal saline for a day, after which their uteri were dissected out and the eggs removed. The eggs so obtained were cultured in order to trace their development, and if possible to attempt some investigations on the life-history of this parasite.

The females are from 12.5 to 19 mm. long with a maximum thickness of .6 mm. in the middle of the body. The males range from 8.5 to 10.5 mm., and the largest specimens are about .345 mm. thick.

The head is bent slightly ventralwards, with the result that the mouth is

tilted slightly dorsalwards. It is laterally compressed and nearly .22 mm. long in a 9.5 mm. long male ; in the same male its dorsal-ventral diameter is .29 mm., and its lateral thickness at its base is .28 mm. The anterior face of the head is rounded, and the mouth is surrounded by six small papillæ, which are the terminations of the three parenchymatous bands of each buccal valve. The buccal valves are about .21 mm. high, and each is thickened at its base in the form of a rounded rim. The duct of the œsophageal gland measures .105 mm., *i.e.*, it extends just beyond the middle of the mouth cavity.

The œsophagus has a more or less uniform thickness in its anterior third, after which it swells to form a slightly oval bulb. In the male mentioned above it is .39 mm. long and the nerve ring is situated at the junction of its first and second thirds. The excretory pore is faint, and is situated .08 mm. from the base of the œsophagus. The cervical papillæ are very small, and are remarkable in that they are situated about .15 mm. *posterior* of the œsophageal bulb.

Female.—The body is attenuated both anterior and posterior to its middle third. In a female 18.5 mm. long the diameter of the body at the base of the œsophagus is .495 mm., in the middle of the body .59 mm., and immediately in front of the vulva .57 mm. Behind the vulva the body narrows abruptly, so that in the same female the diameter of the body immediately behind the vulva is .45 mm. From this point up to the level of the anus thinning takes place gradually, and behind the anus the body tapers more rapidly to form a relatively short and pointed tail varying in length from .18 to .2 mm. in the larger females. The vulva is situated relatively far back, and its position divides the body roughly into the ratio of 8.5 : 1. It is slightly protuberant, but there is no papilliform outgrowth. The vagina is short and leads into the ovejectors, which are not divergent, as in all the other species examined, but convergent. Their combined length is about .545 mm. The uteri are parallel and extend forwards to about 1.5 mm. from the base of the œsophagus.

The eggs are oval, thin-shelled and morulate *in utero* ; they vary in size from .078 to .092 mm. long by .046 to .05 mm. broad.

Male.—The body of the male has a uniform thickness throughout. The bursa is trilobed, and in lateral view has a very obliquely truncated appearance, the dorsal ray being relatively long. The remaining rays are relatively short and thick, but otherwise offer no special peculiarities.

The genital cone is robust and conical, measuring .2 mm. long by .23 mm. broad at its base.

The spicules are long, filiform and slightly alate. They are about .67 mm. long by about .015 mm. broad at their bases. A gubernaculum is present and is about .19 mm. long ; it is, however, very pale and consequently not easily observed.

Types to be deposited in the British Museum (Natural History).

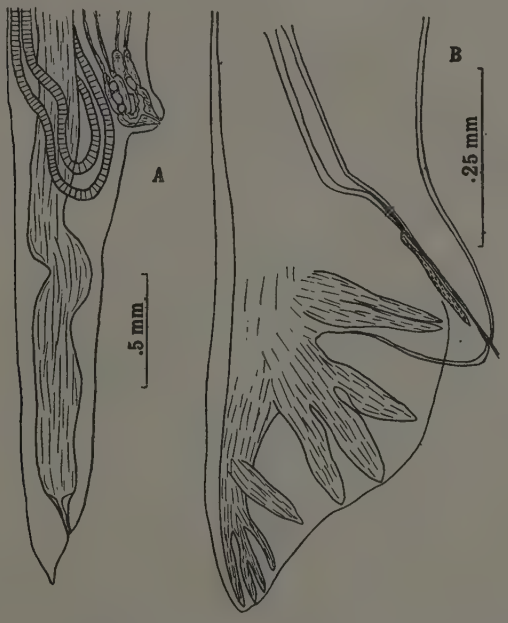

Fig. 12. *Kalicephalus philodryadus*. (*a*) Caudal end, female. (*b*) Bursa.

Observations on the Larval Development.—The females, which had been left in normal saline at ordinary laboratory temperature (about 25° C.), were found to have died overnight. They had, however, laid numerous eggs. With these eggs, and with those obtained after dissection from the uteri, cultures were made in tap water, which were allowed to develop at laboratory temperature.

The eggs, which are laid in an advanced stage of segmentation, undergo development very rapidly, with the result that within the first 24 hours they become fully embryonated and some may even hatch. The first stage larvæ are very active, and are about .312 mm. long by .016 mm. broad. They are rhabditiform, and the œsophagus is .09 mm. long. The buccal cavity is represented in optical section by two straight cuticular rods nearly .012 mm. long. The excretory pore is slightly raised, and is situated about .029 mm. in front of the base of the œsophagus. The nerve ring encircles the œsophagus in its narrow central part, about .012 mm. anterior of the level of the excretory pore. The tail is filiform and nearly .06 mm. long. The genital rudiment consists of an oval and somewhat refractile cell situated ventral to the intestine, and .135 mm. from the tip of the tail.

The first stage larvæ persist for only a relatively short time, because some were seen in the process of ecdysis 30 hours after making the culture.

The second stage larvæ have the same anatomical characters as those of the first stage, but they are larger. During this stage the larvæ grow considerably in size, so that towards the end of this stage on the third and fourth days they may reach a length of .48 mm., with a thickness of .02 mm. The buccal capsule still has the same size as that of the first stage, but the œsophagus has increased to .105 mm. and the tail to .09 mm. The genital primordium has now divided, and consists of two cells.

Towards the end of the fourth day some of the larvæ were seen to have commenced their second ecdysis, and on the beginning of the fifth day the ecdysis was complete. There was, however, no shedding of the cuticle. These larvæ were now in their third stage, and at this stage infection probably takes place. The larvæ now had become very sluggish and only a few passed into the ensheathed condition. This was probably due to the fact that they were not cultured in a nutrient medium, and the reserve food in the body was just sufficient to bring them to the end of the second stage of their development. The fact, therefore, that experiments with ensheathed larvæ to ascertain their powers of skin penetration, resistance to desiccation and response to heat all gave negative results, does not count for much, in that the larvæ were probably too weak to give any definite result.

The ensheathed third stage larvæ are filariform, and are from .48 to .512 mm. long, with a thickness up to .027 mm. The œsophagus is relatively long, and in the largest larvæ measured .148 mm. The buccal capsule has undergone no change.

With the few ensheathed larvæ obtained a grass snake (*Tropidonotus natrix*) was orally fed. Eight days later the snake was killed and a careful examination made of the whole digestive tract and of the lungs for possible developmental stages, but unfortunately with entirely negative results.

Kalicephalus parvus sp.n.

Host. *Coronella getula.*

Locality. North America.

Habitat. Stomach.

The material available for examination consisted of two immature females and one male, which unfortunately broke into two during its examination.

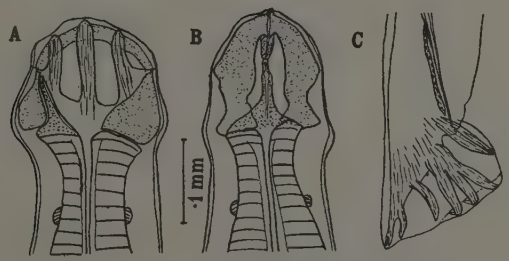

Fig. 13. *Kalicephalus parvus.* (*a*) Cephalic end, male, lateral view. (*b*) Cephalic end, male, dorsal view. (*c*) Bursa.

The females are about 4.5 mm. long and .215 mm. broad at the base of the œsophagus, which is the thickest part of the body. The single male was 3.7 mm. long and .18 mm. thick.

The head is rounded anteriorly and is marked off from the rest of the body by a constriction. In the male it is .185 mm. thick in dorso-ventral diameter, and .155 mm. in lateral diameter. The two buccal valves possess a thickened posterior rim, and are about .135 mm. high in the male, and .147 mm. in the female. The three parenchymatous bands of each valve end in small circum-oral papillæ. The duct of the œsophageal gland is relatively long and extends some distance beyond the middle of the mouth capsule.

The œsophagus is .29 mm. long in the male, and .31 mm. in the female ; the nerve ring is situated just posterior to the junction of its first and second quarters. The cervical papillæ are small and spike-like, and are found about midway between the level of the nerve ring and the base of the œsophagus. An excretory pore was not definitely observed.

Female.—The body is attenuated from the base of the œsophagus backwards. At the base of the œsophagus the breadth is about .22 mm., and at the level of the vulva .17 mm. Immediately behind the vulva the body narrows abruptly, so that the body thickness here is only .11 mm. From the vulva to the anus the body remains about the same thickness, but posterior to the anus the body tapers gently to form a sharp-pointed tail nearly .15 mm. long. The position of the vulva is easily seen, because of the difference of the body width immediately in front of and behind it ; it divides the body into the ratio of 4.3 : 1. The vulva is non-protuberant and leads into a short vagina. The ovejectors are convergent and the uteri run parallel to each other.

No eggs were observed.

Male.—The body of the male tapers slightly from the base of the œsophagus backwards. The bursa is trilobed, the median lobe being slightly notched, and the lateral lobes inrolled. The median terminal branches of the dorsal ray are split for only a short distance at their tips.

The genital cone is very small and flattened, measuring .03 mm. high. The spicules are slender, alate and measure about .27 mm. long by .01 mm. thick at their bases. A distinct and canoe-shaped gubernaculum is present, which is about .098 mm. long.

Types to be deposited in the British Museum (Natural History).

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The Ætiological Relationship of *Loa loa* to Calabar Swellings.

By George C. Low, M.D., M.R.C.P.,

Lecturer, London School of Tropical Medicine.

It has long been held—and rightly so—that Calabar swellings are caused in some way or other by adult *Loa loa* moving about in the subcutaneous tissues.

These swellings appear suddenly, are œdematous in nature, without any true inflammation or redness, last three or four days, and then disappear of their own accord. There is little or no pain ; any that there is being due to the distention of the parts and not, as just said, to proper inflammation. Their geographical distribution coincides perfectly with that of *Loa loa*.

Sir Patrick Manson, who was very interested in the subject, discussed the ætiology of these swellings in a paper entitled " On the nature and origin of Calabar Swellings " as long ago as 1910 (*Trans. Soc. Trop. Med. and Hygiene*, III., 1910, pp. 244-251). He put forward four theories as to their causation :—

(*a*) Lymphatic obstruction. Untenable because the adult worm does not live in the lymphatics.

(*b*) By some irritating glandular secretion emitted from time to time.

(*c*) By fæcal discharges from the alimentary canal of the worm.

(*d*) By periodical and normal emptying of the contents of the uterus of the graved female worm into the connective tissues of the host.

Of these he favoured the latter, and thought he had proved it by aspirating a swelling and finding filarial embryos in the fluid extracted. Unfortunately the blood of the case contained many embryos as well, and the experiment was thus vitiated, the possibility of a contamination from the blood being obvious.

Since that time I have twice carried out a similar experiment ; once some years ago, and again quite lately. In both cases there were no embryos in the peripheral blood and the fluid—serum—from the swellings was quite negative, no embryos being present in it. In Sir Patrick Manson's paper he suggested that for success the following measures should be adopted : the swelling must be quite recent, only of a few hours' standing, and increasing ; secondly, the exploration should be made as near as possible to the point of origin of the œdema ; and lastly, when the aspiration is made the needle point should be in the œdematous tissue.

All these points were carried out to the letter, and serum, uncontaminated with blood, was obtained.

It is unlikely, then, that the swellings are due to an adult female giving birth to young embryos.

Another possibility, so far as I know not suggested before, is that the death of the worm might be responsible. Death of an adult *Filaria bancrofti* often gives rise to serious consequences, but it is true that when they die in the connective tissues abscess usually results.

Calabar swellings, together with many other points, in the life-history of *Loa loa* in man still require elucidation.

Journal of Helminthology, Vol. 1, pp. 193-196.

[L.]

A Contribution to the Experimental Study of the Life-histories of *Hymenolepis fraterna* Stiles, 1906, and *Hymenolepis longior* Baylis, 1922, in the Mouse.

By H. Harold Scott, M.D., M.R.C.P.Lond., D.T.M. and H. Camb., F.R.S.Ed.

Hymenolepis fraterna Stiles, 1906.

Nicoll and Minchin gave an account in 1910, in the Abstract of Proceedings of the Zoological Society of London, of their finding a Cysticercoid in the rat-flea, *Ceratophyllus fasciatus*," very like the scolex of *Hymenolepis murina* Duj. . . . it [*H. murina*] was the only rat-tapeworm to which the Cysticercoid could be referred."

Grassi and Rovelli had previously described direct infection of rats by *H. murina* (*H. fraterna* Stiles, 1906), the cysticercoid developing completely in the villi of the rat's intestine. Joyeux, in 1920, confirmed this, and was of the opinion that the method of direct infection is not an alternative one to that viâ flea-larvæ, but the *only* mode of transmission. He tried many times to obtain development of the cysticercoid of *H. fraterna* in various insects which served as intermediate hosts for *H. diminuta—Tenebrio molitor, Ceratophyllus fasciatus, Xenopsylla cheopis, Pulex irritans*—but with entirely negative results. Clayton Lane and Low (1923*b*) dispute Joyeux' conclusions that *H. fraterna* may pass its entire life-history in the intestinal villi of rats, stating that Joyeux " has no evidence . . . that the cysticercus will develop in that host into a strobilus . . . The definitive host becomes the larval host . . . but the evidence that in this instance the larval host, without being devoured by a definitive host, can give rise to an adult cestode leaves us entirely unconvinced."

With a view to the further elucidation of this question, the following experiments have been undertaken in the Helminthological Department of the London School of Tropical Medicine (since May of the present year) Mice were obtained and kept each in a separate glass receptacle, with a perforated zinc end. The fæces were examined daily for 23 days, and from those who had throughout been found free from infection two were selected and fed with gravid segments of *H. fraterna*. Four days later one of these was killed, and on examination of the intestine considerable

numbers of cysticercoids were seen within the villi. In the upper part of the duodenum only an occasional one was found, the numbers increased as one passed down the jejunum and the upper part of the ileum ; in the lower parts of the latter they were much fewer, while in the cæcum and large intestine none were seen. There were no adults, and the cysticercoids were all apparently at the same stage of development.

Later, in September, this experiment was repeated for confirmation. Two mice which had been among those found free from helminth infection after repeated examinations of the fæces for the preceding five weeks were fed with ova of *H. fraterna*. On the fourth day afterwards one was killed, and the cysticercoids were found as before. The second was left, the fæces being examined daily. On the 24th day ova began to appear, and when the animal was killed several adult cestodes (*H. fraterna*) were found in the lower part of the ileum. During July and August, Woodland (1923) had been carrying out similar experiments and had obtained the same results.

In order to test whether one mouse could play the rôle of intermediate host for another, the mucous membrane containing cysticercoids from the first of these last two mice was fed to a third animal whose fæces had proved negative for the preceding 35 days. Daily examinations of the fæces were made, but no ova were found at any time, and 30 days after the feeding with cysticercoids the animal was killed, but no adult or developing cestodes were discovered.

On October 30th and subsequently a Rhesus monkey was given ova of *H. fraterna* but up to the time of writing (November 17th) no eggs have appeared in the fæces ; one would hardly expect them yet, even if this worm did develop in the monkey.

On July 3rd a considerable number (60-70) of eggs from a human case of *H. nana* were given to two mice, but with negative results. This, however, is merely mentioned incidentally, for the only material available was some which had been put aside for several months. No movement of the embryos was visible in the eggs ; it is very doubtful if they were alive, and still more doubtful if they were viable.

Hymenolepis longior Baylis, 1922.

The life-history of this species has not been worked out, but in the paper in which Baylis (1922) first gives an account of this parasite, he states :

> " There remains one point of considerable interest to be mentioned. As is well known, the researches of Grassi and his collaborators have led to a general acceptance of the theory that *H. nana* (and this covers also *H. murina*) normally passes through the whole of its life-history in the intestine of the same host, its cysticercoid living in the villi of the small intestine, and not requiring an intermediate host. Nicoll and Minchin (1911) found in the body-cavity of one of the fleas that infest rats in this country (*Ceratophyllus fasciatus*) a cysticercoid, of which they observe that, unless it is that of *H. murina*, it must be that of some undescribed form, the scolex of which is indistinguishable from that of *H. murina*. Johnston (1913) also found a cysticercoid in Australia in *Ceratophyllus fasciatus* and another rat-flea, *Xenopsylla cheopis*, which he regarded as that of *H. murina*. Now it seems highly probable, bearing in mind the great similarity between the scolices of *H. nana fraterna* and *H. longior*, that the latter is the adult form into which this cysticercoid develops, and that these cases cannot be taken as evidence that *H. nana fraterna* ever makes use of fleas as intermediate hosts."

A series of experiments similar to the above has been in progress with respect to *H. longior*. A description of this cestode, together with a comparison between it and *H. fraterna* is given by Baylis in *Parasitology* (Vol. 14, No. 1, April, 1922). On November 2nd some gravid segments of a specimen of *H. longior*, obtained from a mouse in whose intestine this cestode only was found (measuring 45 mm. on first removal and 68 mm. after being left in water for half an hour to elongate) were fed to two mice whose fæces had been examined daily for more than five weeks, and had been found free from ova. Four days later one was killed and large numbers of intravillous cysticercoids were seen, all in the same stage of development, while the bowel itself contained no worms of any kind. The accompanying photograph has been taken of a portion of the upper part of the jejunum, and the situation of the cysticercoid within the villus is well shown. In the jejunum and upper part of the ileum one may be found in every three or four fields, and in some places two in a single

field. The second mouse was kept under observation for the appearance of ova. Eggs made their appearance in the fæces of this mouse on November 21st, 19 days after feeding, and three adult worms were found at the autopsy, measuring respectively, when elongated, 32, 33 and 42 mm.

A monkey has also been given some gravid segments of *H. longior*, but sufficient time has not yet elapsed for any definite indications of infection to show themselves, even if such has occurred.

Clearly, however, the cysticercoid stage of *H. longior* can arise, like that of *H. fraterna*, by direct infection of the definitive host, the mouse.

Seeing that the cysticercoids are found in the greatest numbers in the villi of the upper part of the small intestine, whereas the adult worms (of *H. fraterna* at all events) are more abundant in the lower part, one may suggest that the early stages of development take place within the villi high up, and that when these rupture and the scolices are liberated they are carried down the intestine and undergo their further development in the lower part of the ileum.

I would like to express my acknowledgments to Dr. J. A. Murray, of the Imperial Cancer Research Laboratories, for his kind interest and assistance in this investigation.

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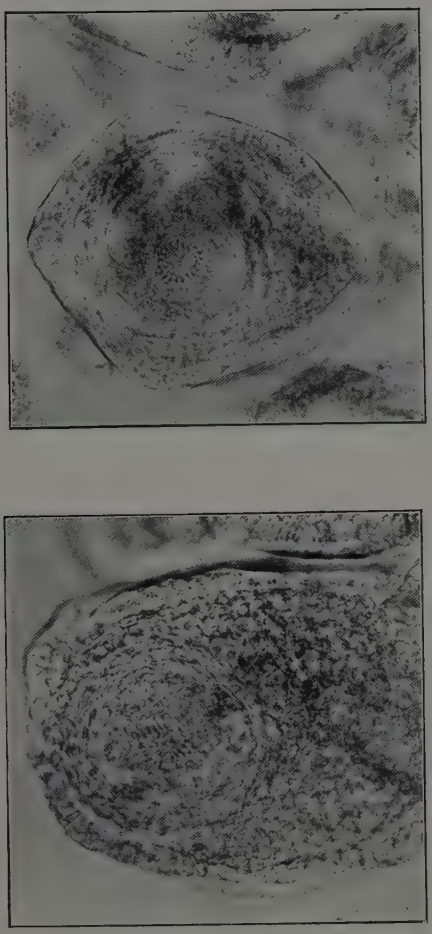

Cysticercoids of *Hymenolepis longior* in intestinal villi of mouse.

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[LI.]

Eelworm Disease of Potatoes caused by *Tylenchus dipsaci.*

By T. Goodey, D.Sc.

Introduction.

In December, 1922, Sir John Russell called the writer's attention to some diseased potatoes which had been sent to the Rothamsted Experimental Station. Dr. W. B. Brierley, Head of the Mycology Laboratory, had examined them and had failed to find evidence of fungal attack though the diseased areas bore a superficial resemblance to the appearances presented by "blight" affected potatoes due to *Phytophthora infestans*. He had, however, found numerous eelworms in the diseased tissues and because of this the writer was asked to examine the material.

A careful microscopical examination of teased tissue showed an absence of fungal hyphæ and the presence of *Tylenchus dipsaci* in all stages of development in the region of the advancing edge of the disease, whilst in the older diseased areas numbers of other saprophytic nematodes, including *Diplogaster*, *Rhabditis* and *Cephalobus* species were present besides an abundance of mites and other small organisms. There could be little doubt, therefore, that the potatoes were suffering from an attack of *T. dipsaci* and that this nematode was the primary cause of the disease, though the subsequent rapid rot of the tubers was doubtless caused by the secondary invaders of various kinds, both animal and vegetable.

The potatoes examined at that time had been taken from pits in which practically all the stock had rotted so rapidly that only a small proportion could be saved and this was unsaleable for human consumption.

The disease has again cropped up in certain potato growing areas in the county of Lincoln, and a recent examination of the affected tubers in the field and in the laboratory furnishes the occasion for the present note.

Previous Work.

So far as can be ascertained, no previous record of the occurrence of the disease in England exists and it is probable that it has generally

been confused with potato " blight." As regards this, however, there is good evidence that it has been found in stocks taken from fields where no " blight " has occurred.

A reference to the literature shows that the disease occurred in Germany many years ago and was described by Kühn (1888) under the name *Wurmfäule.* A full account of it together with some experimental work on it was also given by Ritzema-Bos (1892) who called it " *La maladie vermiculaire des pommes de terre.*" Both these workers distinguished it from " blight " and Ritzema-Bos laid particular stress on the rapidity of the decay of stored tubers. A short résumé of this investigator's article is given herewith.

He notes that the disease has probably been confused with " blight " and that consequently it has probably been present for several seasons without its true character being known. Not all the varieties grown in an affected area show the disease, and this was Kühn's experience also. The varieties cited by him as showing the disease are *Champion, Americain* and *Turc,* whilst Kühn's susceptible variety was *Eos.* He suggests that the disease was introduced by infected seed potatoes and notes that the outbreak of the disease in Holland coincided with that in Germany in 1888.

Experimental work on the disease proved very difficult for infected tubers could not be kept during the winter owing to the almost complete rot which set in. Moreover healthy potatoes set in soil of known infectivity for *T. dipsaci* in Rye failed to show any sign of the disease at all. He succeeded in getting two plants to grow from affected tubers and on these his observations are based. He had noticed in the aerial portions of diseased plants sent to him by a correspondent that the stems were thickened and brittle, and that the leaves were curled and wrinkled, but had failed to find any *T. dipsaci* in them. The leaves also bore yellowish brown spots here and there similar to those found on Narcissus leaves suffering from *T. dipsaci.* In the two plants grown from diseased tubers the same appearances were presented by the stem and leaves, viz., the stems were swollen and twisted, whilst the leaves were curled and wrinkled and bore yellowish spots. In these two plants he succeeded in finding *T. dipsaci* in the aerial parts. In the underground parts of the plants he noted that the rhizomes were often irregularly curved and swollen at certain points. The tubers were small or scarcely formed at

all owing to the destruction of the foliage. Where tubers were formed the first point to show the attack was in the vicinity of the attachment to the rhizome showing that the worms had passed from the latter to the tuber. On the tubers themselves the disease revealed itself first as one or two dark discoloured areas which later increased in size and became confluent. When cut across, these areas showed as brownish patches, loosely granular in consistency penetrating into the substance of the tuber for a short distance. In these regions he found *T. dipsaci* plentifully.

Returning to his general observations on the disease he noted that at the time of lifting and towards winter, the diseased spots coalesce and a rapid rot ensues which involves the whole of the substance of the tuber and reduces it to a soft putrid discoloured mass only the skin being left. Kühn did not observe such rapid rotting conditions in his cases. This would, no doubt, depend on the state of moisture of the potatoes when stored in the pit. He further noticed what Kühn had already found that as the tubers rot the numbers of *T. dipsaci* gradually diminish and finally disappear, having been destroyed by the putrefaction set up.

With regard to the occurrence and spread of the disease Ritzema-Bos makes various suggestions :—

1. Infected seed potatoes may be the occasion of the onset of the disease.
2. Diseased potatoes may be left in the soil and so give rise to the disease again when susceptible varieties of potatoes are planted.
3. The parasites which are capable of attacking certain weeds may go into these for a time and then attack potatoes when these are planted on the same areas.
4. Diseased tubers being unsaleable for human food should be fed to cattle after first being cooked.
5. Sprouting diseased tubers should not be thrown on to the manure heap as by this means they will finally aid in the further distribution of the parasites on the fields.

Occurrence in Britain.

The disease is not of recent occurrence in this country as a grower informs the writer that he has seen it on and off for the past 12 years, not only in the Eastern Counties but also in Scotland. He has been aware

of the fact that it is different from " blight " in spite of the fact that diseased tubers examined by certain experts had been proclaimed by them to be suffering from " blight " ; evidently the superficial resemblance between the two diseases had been responsible for this judgment. During the last three or four years, however, the disease appears to have increased or has been more carefully observed.

The writer's experience of the disease in the field is confined to a recent inspection of tubers growing in soil in which potatoes had suffered badly from the same disease in 1921.

Symptoms.

The stems and foliage of the plants showed no signs of disease, in fact the plants were to all appearances in a fine healthy condition and gave promise of a good crop. The ground had been well manured and during 1922 had been cropped with oats which were quite healthy. Enquiry on this point was particularly sought by the writer to elicit if any signs of " tulip-root " had been observed. The variety of potatoes on one half of the field was *Aran Chief* and on the other *King Edward*. When roots of the former were lifted it was found that in spite of the healthy appearance of the haulm and foliage, many of the tubers at a root were diseased. A careful examination of the haulm and foliage failed to reveal any signs of distortion or curling and wrinkling such as were observed by Ritzema-Bos. It may, therefore, be said that there was an entire absence of symptoms from the stems and leaves which would lead one to suspect the presence of the disease. The tubers on the other hand showed well marked symptoms of the disease in several stages of progress, some being only slightly and others more severely affected.

Discoloration of the surface in small patches was apparent but more frequently there was a breaking down of the skin with an obvious destruction of the underlying tissues. When cut across, the diseased areas were found to extend for a short distance into the substance of the tuber as a brownish discoloration ; the newly attacked areas being paler in colour than the older ones. Fig. 2b shows the sort of condition occurring in a far advanced state of rot.

Several roots of *Aran Chief* were lifted in the field and in every case diseased tubers were found. Moreover there was every indication that the nematode was attacking the tubers direct from the soil and not by

way of the plant. The attack in fact appeared to be a late one and had not been primarily directed at the plant. This difference from Ritzema-Bos' observations is interesting and suggests that in this particular instance the parasites had not been introduced with the seed, as in this case they would presumably have attacked the growing plant, but had remained dormant in the soil since 1921. There can be no doubt that had the plants manifested symptoms of disease in the aerial regions these would have been noticed earlier by the growers themselves. Several diseased tubers were found attached to perfectly healthy rhizomes, the affected areas being at the end of the potato furthest from the point of attachment. This also demonstrates fairly conclusively that the tubers and not the plant were the first to be attacked.

Microscopic examination of small quantities of diseased tissue showed *T. dipsaci* in abundance in all stages of development. In some spots no other nematodes were found and this was particularly the case where the disease had not proceeded very far. In older diseased areas *Diplogaster* and *Cephalobus* species were plentiful. No mites were observed at this time, but what appeared to be the larval stages of an insect were seen.

Another point of interest is that the *King Edward* did not appear to be attacked. After digging about 12 roots chosen at random on the field, some near the *Aran Chief* and others further away, only one root was found which carried two slightly affected tubers. Another field was visited which had borne a crop of *Aran Chief* in 1921 when the tubers were badly affected by this disease. In 1922 wheat was grown and this year it is again being cropped with potatoes of *King Edward* variety. Several roots were lifted in that part of the field where there had been most disease in 1921, but in no case could any disease be found. It would seem from this that *King Edward* is only slightly susceptible to attack from *T. dipsaci*. This accords with the observations of Kühn and Ritzema-Bos who, as already noted, found that only certain varieties were attacked.

Discussion and Suggested Remedies.

No well-marked symptoms of disease show themselves on the stems and leaves, and for this reason the early detection of the disease is practically an impossibility. This fact makes it very difficult to adopt any reliable defensive measures.

The capacity of the worms to remain quiescent and to resist desiccation are considerable. In a previous paper the writer has shown (1923) that *T. dipsaci* attacking Narcissus bulbs and Onions can be revived from a dry condition after a lapse of two years at least. There is every likelihood, therefore, that the potato parasite would remain dormant in the soil for quite as long a time and possibly longer.

It is probable also that the parasite resembles the *T. dipsaci* attacking other cultivated plants in being a " biologic strain " peculiar to the potato crop. The fact that it did not attack the oats grown on the field in 1922 lends support to this view. It must, however, be admitted that we know very little of the nematode's capabilities of trans-parasitisation from crop to crop.

The disease presents many obscure factors, and our present knowledge of it is so slight that the recommendation of adequate remedial measures is a difficult matter. The following suggestions, however, may prove of value :—

1. As the disease has so far only shown itself on *second earlies* or *late* varieties of potatoes towards the time of ripening, the use of *early* varieties may be recommended.

2. If late kinds are grown those should be selected which are proved to be unaffected by the disease. At present *King Edward* seems to be only slighted attacked whilst *Aran Chief* is badly affected. Valuable information would probably be obtained if a large range of different varieties could be tested on land which has carried the disease so as to ascertain which are resistant and which susceptible. Knowledge is also required as to whether a given variety will retain its power of resistance or will finally become susceptible to the parasite.

3. Only perfectly sound undiseased seed potatoes should be used and great care should be exercised to ensure this.

4. Where the disease is present special precautions should be taken in lifting the tubers to ensure that no diseased ones are left in the soil to perpetuate the malady. Where it can be done the affected tubers should be fed to farm animals after being steamed or otherwise suitably cooked. Little can be done to save them if the potatoes are once put into pits and rotting sets in.

5. As a radical remedy the treatment of infected soil by heat may be recommended though in the present difficult economic condition of

British agriculture this recommendation is probably impracticable and an unattainable ideal. The writer has recently suggested, in a paper on certain other nematode diseases of plants due to members of the genus *Aphelenchus* (1923a) the use of a machine devised by Richards and Guiness for the heat treatment of soil. This machine would lift the top 6 or 9 inches of soil, break it up, submit it to a blast of hot gases and then drop it again. The parasites are killed at comparatively low temperatures, 50°—60° C. such as would be obtained by the combustion of much smaller quantities of fuel than would be required for the partial sterilisation of the soil by the same process, and it is worth pointing out that the machine has been shown to be capable of effecting this process in the field.

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Explanation of Plate.

Fig. 1. Photograph of 2 diseased tubers, showing external appearance; (*a*) is only slightly attacked at its upper end, whilst (*b*) is extensively diseased. ½-natural size.

Fig. 2. Photograph of two diseased tubers cut across to show depth of affected areas; (*a*) is in an early stage of the disease; (*b*) has far gone in rot. ½-natural size.

Fig. 3. Photomicrograph of 2 specimens of *Tylenchus dipsaci* from a diseased tuber. Female worm above, male below. The larger foreign bodies are starch grains. X. 70.

Fig. 4. Photomicrograph of head end of *T. dipsaci*, showing mouth stylet, the œsophageal bulb, the spatulate termination of the œsophagus and the granular beginning of the intestine. X. 360.

Fig. 5. Photomicrograph of male tail of *T. dipsaci* showing the spicules and one of the wing-like expansions of the cuticle attached to the sides of the body. X. 360.

Tylenchus Dipsaci in Potatoes.

Journal of Helminthology, 1923, *Vol.* 1, *pp.* 205-214.

[LII.]

On the biology of the infective Larva of *Monodontus trigonocephalus* (Rud.) of Sheep.

By T. W. M. Cameron, M.A., B.Sc., Ph.D., M.R.C.V.S.

Introduction.

The biology of the infective larva of the Sheep Hook-worm *Monodontus trigonocephalus* would be expected on general grounds to resemble that of *Ancylostoma duodenale*, to which it is closely related. Two facts in the biology of the adults must, however, be borne in mind. In the first place, the normal temperature of man is about 37° C., while the normal temperature of the sheep is 39°–40° C. Secondly, both Looss (for *A. duodenale*) and Hesse (for *M. trigonocephalus*) have shown that the pre-infective larvæ feed actively on fæcal matter. Looss has drawn attention to the fact that cultures of Ancylostomes made from the fæces of a host living on an exclusively herbivorous diet, were very much poorer in the resultant crop of larvæ than those made from fæces of a host living on a partly carnivorous diet. Now the adult *Monodontus* lives in a host which is purely herbivorous, and the larvæ are reared in fæces entirely of a vegetable nature. One might therefore expect differences in the biology of the ensheathed stage.

Technique.

Culture Methods.—Eggs were obtained from teased up female worms, so that there could be no possibility of a mistake as to the identity of the larvæ.

At first, attempts were made to cultivate the larvæ in plain water. Only a small proportion of the larvæ reached maturity, and these, being feeble and ill-nourished, soon perished. It was felt that such larvæ might not show the normal reactions, and consequently they were discarded. On subsequent occasions the eggs were cultivated in a mixture of sheep fæces and fresh animal charcoal. As it is practically impossible to get sheep fæces free from parasitic ova, all the material used as culture medium was heated in a water bath at 70° C. for half an hour. Controls, to which *Monodontus* eggs had not been added,

were incubated under identical conditions and found to be sterile. There is, therefore, no possibility that the larvæ used in these experiments were other than *Monodontus*.

The cultures, made in Petri dishes, were incubated at 22° C. for five days. By this time the semi-solid fæcal mass had acquired the consistency of butter. As the larvæ neither climbed to the filter paper with which the lid of each Petri dish was lined, nor were able to penetrate filter paper in a funnel, they could not be recovered from the culture by the technique which serves for the isolation of Ancylostome larvæ. Accordingly the surface of the culture was carefully flooded with water at a temperature of 40° C. After five minutes this water was decanted without disturbing the fæces. By this means large numbers of larvæ were obtained daily until the culture was exhausted. By this technique the larvæ were isolated in practically pure water, and in a well nourished and robust condition.

Temperature Reactions.

Several experiments were undertaken to discover the effect of temperature on the larva.

A small electrically heated stage was attached to the microscope, and a glass slide placed thereon. A drop of water containing a suspension of larvæ was added, and the current switched on. The following movements of the larvæ (in water) were observed at all the temperatures registered by the instrument :—

15°–22° C.—The movements were very lethargic at 15°, but motility slightly increased at 22°.

22°–35° C.—Activity was increased intermittently.

35°–40° C.—Larvæ were very active, moving from place to place and lashing their tails.

40°–47° C.—The larvæ became less active, and the movements more spasmodic.

On switching off the current after half an hour at 47° C. the larvæ, as the temperature fell, went through a reverse series of changes, and finally returned to their original lethargic state.

This experiment was repeated, using a Leitz electric stage with a maximum of about 90° C. In this case also the movements increased in rapidity until they reached their maximum about 40° C. Thereafter the movements became more spasmodic and jerky, finally ceasing at 62° C. None

of the larvæ recovered. In a parallel experiment in which the maximum temperature reached was 60° C., although this temperature was maintained for five minutes, all the larvæ recovered on returning to 15° C.

At temperatures of 18° C. and under the larvæ are very lethargic, and the majority are motionless. Some larvæ were frozen in a glass capsule on an ice and salt mixture. Although only frozen for a very few minutes, none revived on returning to room temperature. A second experiment in which the temperature reached was 4° C., gave a similar result. In an experiment with a minimum temperature of 6° C., the larvæ were able to recover.

It will be noticed that the optimum temperature of *Monodontus* larvæ is slightly higher than that of the human Ancylostomes. This may, perhaps, be correlated with the fact that the body temperature of the sheep is slightly higher than in man. Ancylostome larvæ of human origin are able to resist freezing : as also is *Hæmonchus contortus* of the sheep.

Desiccation.

Experiments on the resistance to drying of these larvæ showed that it was very poor indeed. Larvæ placed on a glass slide and allowed to dry completely, never revived. If, however, when nearly dry, the slide was placed upside down on the edge of a Petri dish containing water, the larvæ were found to live indefinitely, as the water vapour prevented complete desiccation. Larvæ placed on blades of growing grass, however, did not obtain sufficient moisture to prevent their death. The completely dried larva, when placed in water, swells up, and in an hour or so has resumed its former size and shape, but it never regains its vitality.

Larvæ placed upon the skin, as in the skin penetration experiments, can survive apparent desiccation for nearly an hour. *Necator* larvæ, under similar conditions, if they have not penetrated the skin, do not survive for more than a few moments. Accordingly one is justified in concluding that their power of resisting desiccation, though feeble, is somewhat higher than *Necator*. It has been shown that in the cases of *Hæmonchus contortus* and *Syngamus trachealis* a somewhat similar state of affairs exists ; although, in the first case, the resistance is greater than in *Monodontus*. On the other hand, *Heligmosomum muris*, *Nematodirus* and the horse Strongyles will withstand *complete* desiccation—in the first case for a few days, in the others for some considerable time.

Geotropism.

On no occasion were larvæ found on the blotting paper in the cover of the Petri dishes. As these cultures were incubated at 22° C., it was thought that the temperature was possibly too low to induce climbing, but the larvæ did not climb in cultures which were incubated for several hours—in one case for six days—at 37° C., precautions having been taken to prevent the blotting paper becoming dry. A small piece of stick, thoroughly moistened, was placed in a culture and observed after having been exposed to a temperature of 22° C. and at 39° C. In neither case did the larvæ climb.

In certain experiments conducted at 39° C. in solid watch glasses, it was observed that if they could overcome the surface tension, and if the gently sloping walls were moistened, the larvæ could wriggle out of the main body of water and climb up a certain distance—about their own length. Very little moisture was required. This cannot really be termed climbing, however, as the slope of the glass was very gentle.

These cultures were made under the optimum conditions for climbing, as it had been observed that *Necator* larvæ climb best from a semi-solid medium. In a watery medium they tend to remain in the fluid. The majority of Strongyle larvæ hitherto investigated are active climbers, *Syngamus* being one of the exceptions. (Ortlepp, 1923.)

Thermotropism.

Khalil (1922) has shown that the larvæ of *Ancylostoma duodenale*, *A. ceylanicum*, *Necator americanus*, *Galoncus perniciosus* and *Trichostrongylus douglasi* were positively thermotropic, whereas the phenomenon was absent in *Hæmonchus contortus*. Hesse states that the larvæ of *Monodontus trigonocephalus* are negatively thermotropic, *i.e.*, they move away from the source of heat. A series of experiments was undertaken to investigate this point. A warmed needle was brought near to the under side of an ordinary watch glass containing a number of larvæ in suspension. The larvæ orientated themselves until their heads were pointed towards the source of heat; they then progressed rapidly towards this point. They moved with vertical flexions of their body, and very quickly formed an undulating "star" round the point of the needle. This experiment was repeated over and over again with similar results. It is obvious, therefore, that Hesse's observation cannot apply

to this worm. It was also found that the larvæ swim upwards to the source of heat, and maintain themselves in position against the action of the convection currents, as was noted by Khalil for the other thermotropic larvæ. It was remarkable how small an amount of heat was necessary to cause the larvæ to become active. Breathing on a slide was generally sufficient to induce it.

Khalil suggests that thermotropism may be connected with the ability of the larvæ to penetrate skin. As the experiments related in this paper show, *Monodontus* larvæ, which are actively thermotropic, are not skin penetrators. Khalil's reaction certainly cannot be taken as a positive indication that larvæ are skin penetrators. This conclusion is supported by the case of *Ornithostrongylus douglasi* on which Khalil experimented. The larvæ are shown by him to be thermotropic; yet Theiler and Robertson (1915) have shown that these larvæ do not penetrate the skin, infection taking place by ingestion.

Phototropism.

These larvæ are markedly positively phototropic. In Petri dishes, placed near a window, the larvæ are found almost entirely on the lighted half of the culture, the majority being close to the edge. The same effect follows when they are exposed to diffused daylight or to direct sunlight, or even to electric light. Larvæ lying motionless at 20° C. can be stimulated to activity by exposure to light. They suffer no harm from lying in front of a window.

Phototropism varies among the other Strongyles, the life-history of which has been worked out. In *Ornithostrongylus douglasi*, *Hæmonchus contortus*, and *Heligmosomum muris* direct sunlight seems to be injurious. The first-named species is negatively phototropic, the second positively phototropic, though to a moderate degree; while the last seems to be negatively phototropic. *Ancylostoma* spp. and *Necator*, according to Looss, suffer no harm from the action of direct sunlight; but the sunlight may accelerate decomposition processes and so indirectly kill the larvæ. Experiments made with Ancylostome larvæ from a human source seem to indicate that these have no phototrophic properties.

Thigmotropism.

Looss explains that the ability of an Ancylostome larvæ to penetrate the unbroken skin is due to their inherent ability to penetrate cracks and

fissures. He notes that the larvæ will for the same reason penetrate the pores of filter paper ; in fact, this principle can be used for collecting the larvæ from fæcal cultures.

A piece of filter paper was fastened to a cork ring and floated on water at a temperature of 40° C. A suspension of larvæ was placed on the upper surface and observed through a binocular microscope. The larvæ were seen to move at a remarkable speed across the surface of the filter paper by means of lateral flexions of their bodies. In no case, however, did they attempt to penetrate the pores of the filter paper, and after an hour, when the paper was removed, all the larvæ were recovered from the upper surface. It was noted that after half an hour at 40° C. they lost most of their motility, as though the rapid movements had exhausted their available stock of energy, yet they recovered their motility again in about an hour at room temperature.

When cultures were placed in filter funnels lined with filter paper, larvæ were absent from the filtrate.

Skin Penetration Experiments.

A series of experiments was undertaken to determine whether or not the larvæ were able to infect the host through the skin. The technique followed was that described by Goodey (1922).

The abdominal skin of a four-day old rat was stretched, hair upwards, on a cork ring and floated on warm saline at a temperature of 37°–39° C. A drop of water containing some fifty active larvæ in suspension, was placed on the skin and the whole observed under a binocular microscope.

The activity of the larvæ markedly increased when they were placed on the skin, but the rapid burrowing motion observed in the case of *Necator* was absent. As the water evaporated the larvæ became much less active and finally quiescent. A drop of water at 39° C. was added, and motility immediately returned. Finally the larvæ were allowed to dry completely, and were placed in an incubator at 37° C. for two hours. A drop of water was added to the spot where the larvæ had been and removed in a pipette to a glass slide and examined. All the larvæ were found to be present, and were still in their sheaths. None recovered their motility. The desiçcation at the high temperature had apparently killed them. This experiment was repeated with fresh lots of larvæ not only by the writer but also by Dr. Goodey. In both cases the results were the same.

A similar experiment was performed with a piece of buccal mucous membrane newly stripped from a sheep, and not permitted to grow cold. This was floated on a cork ring on saline at a temperature of 40° C. The larvæ again failed to penetrate, although they remained alive rather longer than on the rat's skin.

Adopting a similar technique, a small piece of abomasum from a sheep was floated on saline at 40° C. A large number of larvæ in suspension was placed on this. None of the larvæ penetrated the mucous membrane, but all exsheathed. This experiment was confirmed repeatedly.

The larvæ already used on the abomasal mucosa were placed on small pieces of intestine on saline at the same temperature. They showed burrowing movements, forcing their way downwards between the villi. On fixing the pieces of tissue in alcohol, and clearing in lacto-phenol, only one larva could be found, but it was impossible to say whether it was between two villi or whether it was in the submucosa.

An experiment was undertaken to test the penetrative power of the larvæ on the human skin. A drop of water was placed on the back of the hand on a spot between the fingers where the skin was thinnest, and allowed to evaporate. After a short time—about twenty minutes—a drop of water was placed on the same spot and removed to a slide. All the larvæ were recovered from this drop, the majority being still alive.

Using the same technique, a control experiment was made with *Ancylostoma ceylanicum*, a known skin penetrator. This gave positive results, as was shown by the recovery of cast empty sheaths from the spot where the larvæ had been placed twenty minutes earlier.

Duration of Free Life.

The maximum duration of life in the free state of the infective larvæ under optimum conditions has not been ascertained, but larvæ will live in clean water for several months without difficulty, provided they have been well fed in their first and second stages. If they have been cultivated from ova in clean water they are much more delicate and quickly die. This seems to be due to starvation, as the intestinal cells are almost free from the food granules seen in those larvæ which have been raised in æcal cultures.

The Effect of Aniline Dyes on the Larvæ.

In 1911, Looss showed that Ancylostome larvæ, when treated with 1 per cent. fuchsine, did not absorb the stain, but, under suitable circumstances, escaped from their sheaths, which alone became intensely coloured.

Goodey (1922) showed that this was true also for *Necator* larvæ; but that *Hæmonchus* and *Graphidium*, which do not penetrate the skin, absorbed the stain and died.

Monodontus larvæ were placed on a slide and covered with a cover-slip. Only just sufficient water was used to enable the larvæ to move, and a few drops of 1 per cent. fuchsine was placed at the edge of the cover slip and allowed to run in. The larvæ became very active on first contact with the stain, but rapidly absorbing it, coiled on themselves and died. No attempt was made to exsheath, and the larvæ absorbed the dye to the same extent as the sheaths. A similar result was obtained with methyl-green.

From the results of experiments made on Strongyle larvæ with analine dyes, it is interesting to note that all skin-penetrators which have been tested have exsheathed, while the non-skin-penetrators have not ex-sheathed but have been quickly killed.

General.

It will be noticed that the results of the present series of experiments differ from those of Hesse (1923) in three particulars.

(1) *Resistance to desiccation.* Hesse stated that the larvæ are very resistant to desiccation, whereas those used in my experiments showed feeble resistance.

(2) *Thermotropism.* Hesse's larvæ were negatively thermotropic, whereas mine are definitely positively thermotropic.

(3) *Optimum temperature.* The optimum temperature in the case of Hesse's larvæ was 22° C., in mine in the neighbourhood of 39° C.

Hesse made his cultures in Scotland from sheep fæces from which he stated he had removed all the helminth ova. This is a very difficult thing to do; and it is suggested here that his results may be explained best as obtained through an accidental contamination with ova of *Nematodirus* spp., a very common Nematode in Scottish sheep. In order to determine

this point cultures were made from teased up female Nematodirus, and precautions taken to obviate contamination. Experiments similar in technique to those described above were made to clear up these points.

(1) *Desiccation.* The infective larvæ of *Nematodirus* were found to withstand desiccation very well. Boulenger (1915) has already drawn attention to their extremely resistant properties.

(2) *Thermotropism.* A hot needle, of about the temperature required to strongly attract *Monodontus* larvæ, caused *Nematodirus* larvæ to coil on themselves and remain motionless. These larvæ regained their motility in a few minutes after the removal of the needle. A slightly lower temperature caused the larvæ to move away from the source of heat, *i.e.*, they are *negatively* thermotropic, although not to a very marked degree.

(3) *Optimum temperature.* The optimum temperature for these larvæ is about 23° C. At temperatures above 25° C. the larvæ coil on themselves and remain quiescent.

It was found that the *Nematodirus* larvæ used in the above experiments made no attempt to climb from the cultures on to the blotting paper lining the lid of the Petri dishes—in this point differing from Boulenger's results. The larvæ also were obtained after eighteen days' incubation at 25° C., a shorter period than was found by Boulenger.

There seems to be no reasonable doubt that Hesse's biological observations were made on material contaminated by *Nematodirus*. His morphology, however, was based on pure cultures, as there is no possibility of mistaking the three free larval stages of *Monodontus* for the single free larva of *Nematodirus*, with its peculiar tricuspid tail.

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A Filarial Survey in British Guiana, 1921

By J. Anderson, M. Khalil, C. U. Lee and R. T. Leiper
(*Members of the Filariasis Commission of the London School of Tropical Medicine.*)

The Filariasis Commission, composed as it was of British, Chinese, and Mohammedan members, was able to take a more extensive and a more representative survey of the incidence of filariasis than would have been possible in the case of a single investigator. Dr. Khalil had frequent invitations to local Mohammedan ceremonies, and as these were usually held at night, he was able to examine a large number of blood-films from East Indian immigrants. Dr. C. U. Lee was very hospitably received by the Chinese families of Georgetown, and collected statistics as to the filarial rate amongst them on a scale that was hitherto unattainable. The whole commission, working together, was able to undertake a survey of an institution such as Georgetown Prison, the Almshouse, or Christchurch Public School with little inconvenience to the children or inmates. Thus from hospitals, schools, prisons, asylums, and domiciliary visitations, the Commission collected details and examined blood-films from 4,215 inhabitants of British Guiana. The total number of examinations was made up as follows :—

Cases examined at random in Georgetown	2,434
,, ,, ,, country districts	785
Patients attending the Night Clinic for Filariasis at Georgetown Public Hospital	865
Aboriginal Indians	131
Total	4,215

In the examination of these blood-films 835 or 19·8 per cent. showed microfilariæ of different types.

Technique.

It was found most convenient to take specimens of blood from the lobe of the ear. The lobe was rubbed vigorously with spirit and allowed to dry. With a straight surgical needle a puncture was made, and a drop of

blood was collected on a microscope slide. This drop was then spread in a thick film by the aid of the needle. Where accurate microfilarial counts were necessary, a hæmocytometer pipette was used, and 20 cubic millimetres of blood were placed on each slide. This quantity was taken as the standard in all the therapeutic tests.

As a routine practice in the examination of bloodfilms it was found unnecessary to use any stain. In many cases the fresh blood-film was examined on the spot, and the active movements of the microfilariæ seen under a 2/3 in. lens made an immediate diagnosis possible. Generally, however, the films were allowed to dry, and were then taken back to the laboratory for careful scrutiny. There the films were de-hæmoglobinised in a tray of distilled water, and examined microscopically while still wet. If the slide had been allowed to dry, the embryos could still be detected, but they did not stand out so clearly under the low power as in the wet state.

Filarial Survey.—British Guiana.

Historical.—Infection by *Filaria bancrofti* was probably introduced into British Guiana and the West Indies by slaves brought from West Africa. Some of the old inhabitants state that various manifestations such as elephantiasis and "rose" were not uncommon in the middle of last century, and they are convinced that in the last seventy years the infection has steadily become more widespread. The presence of microfilariæ in the blood was first recognised, it is believed, by a Dr. Hillis about the year 1877, shortly after Lewis and Manson had published similar observations in India and China.

In May, 1883, Dr. Grieve, when Medical Superintendent of the lunatic asylum, published a paper in the asylum journal showing the percentages of persons of different races in the institution who were suffering from elephantiasis. From a survey of 400 patients he found this disease in 21 or 5·2 per cent. He considered that as insanity could hardly affect the incidence of elephantiasis, his figures would give a fairly accurate indication of the proportion of the disease in the colony.

Interest in the subject was next stimulated by Dr. Daniels[1], who described in 1896 some specimens of adult worms found in the course of an operation for the removal of an inguinal cyst. These he identified as *Filaria bancrofti*. In the same periodical he published, in collaboration

[1] "British Guiana Medical Annual" for 1896, p. 62.

with Dr. Conyers[2], a filarial survey of the patients in Georgetown Hospital. In one group of 752 persons examined they found 9·1 per cent. suffering from elephantoid disease ; and 348 blood examinations showed microfilariæ in 14·9 per cent. of the cases.

In the following year Dr. A. T. Ozzard[3] announced his discovery of a new species prevalent amongst the aboriginal Indians on the Demerara River, which came to be known later as *Filaria ozzardi*. Dr. Daniels[4] at once confirmed the discovery, and described the parasite.

In 1902, Dr. G. C. Low[5], of the London School of Tropical Medicine, visited British Guiana during his researches in the West Indies, and wrote a very suggestive paper on " Filarial Lymphangitis." Dr. K. S. Wise[6] took up the quest from this point, and in 1907 he published his pathological and bacteriological observations on the grave septicæmic conditions which he called " Abdominal Filariasis." In the following year he drew up statistics[7] regarding the filarial rate amongst the patients in Georgetown Hospital, and in a total of 493 persons examined he found filarial embryos in the blood in 13·0 per cent.

Wise continued his work on the bacteriology of filariasis, and published several papers in the Reports of the Committee for the Tropical Diseases Research Fund. In 1915, Dr. F. G. Rose[8] described the first results of his treatment of filarial conditions by vaccines, a promising therapeutic agent which has been elaborated and employed up to the present day. Rose also made a more extensive survey of the filarial rate than had hitherto been attempted, and he published his results in a Report to the Committee of the Tropical Diseases Research Fund in 1920.

The four different surveys thus conducted over a period of 40 years pointed to a steady increase in the proportion of persons infected. To what extent this apparent increase might be discounted by the more modern methods of examination is an open question.

Tables I. to IV. summarise the findings in the total of 4,215 blood-films examined by the Filariasis Commission in 1921.

Tables I. and II. show a heavy infection with *Filaria bancrofti* throughout the Colony, but particularly in the city of Georgetown. They also

[2] " British Guiana Medical Annual " for 1896, p. 42.
[3] Ibid for 1897, p. 28. [4] Ibid, p. 24. [5] Ibid for 1902, p. 1.
[6] Ibid for 1907, p. 134. [7] Ibid for 1908, p. 35. [8] Ibid for 1915, p. 7.

show that while all races are liable to infection, the highest rates of incidence are found amongst the Blacks, the Mixed races and the Portuguese.

TABLE I.

Inhabitants of Georgetown taken at Random.

Race.	Males.			Females.		
	Number examined.	Number with Microfilariæ.	Percentage.	Number examined.	Number with Microfilariæ.	Percentage.
Blacks ...	614	189	30·78	397	119	30·0
Mixed Races ...	171	46	26·90	216	46	21·3
East Indians ...	275	34	12·36	140	13	9·3
Portuguese ...	63	15	23·81	61	13	21·3
Chinese ...	209	21	10·05	222	10	4·5
Europeans ...	53	5	9·43	13	1	7·7
Total ...	1,385	310	22·38%	1,049	202	19·26%

TABLE II.

Country Districts taken at Random.

Race.	Males.			Females.		
	Number examined.	Number with Microfilariæ.	Percentage.	Number examined.	Number with Microfilariæ.	Percentage.
Blacks ...	273	41	15·0	80	12	15·0
Mixed	22	5	22·7	14	1	7·1
East Indians ...	295	35	11·9	31	2	6·5
Portuguese ...	4	—	—	3	—	—
Chinese ...	8	2	25·0	3	—	—
Europeans ...	48	4	8·3	4	—	—
Total ...	650	87	13·4%	135	15	11·1%

TABLE III.

Night Clinic for Filariasis, Georgetown Public Hospital.

	Number of Cases.	Number with Microfilariæ.	Percentage.
Elephantiasis	434	42	9·67
Other manifestations	275	120	43·63
Healthy relatives...	156	30	19·23
Total	865	192	22·8%

TABLE IV.

ABORIGINAL INDIANS.

	Number examined.	Number with *F. perstans.*	*F. ozzardi.*	*F. perstans* and *F. ozzardi.*	*F. bancrofti.*
Males	90	10	4	4	1
Females... ...	41	8	—	4	—
Total ...	131	18	4	8	1

It is interesting to compare the percentage of infection shown in Table I. with the findngs of previous observers in the same area. Table V. is divided into four columns to show the percentage of cases infected with *F. bancrofti* in four different surveys carried out during the past 25 years.

TABLE V.

GEORGETOWN AND DISTRICT.

		A. 1896.	B. 1908.	C. 1919–20.	D. 1921.
Numbers examined ...		—	—	351	2,434
		%	%	%	%
Blacks ...	...Male	13·0	10·2	24·8	30·8
	Female	24·0	16·8	26·0	30·0
Mixed ...	...Male	14·2	18·3	27·3	26·9
	Female	24·0	16·8	21·4	21·3
East Indians	...Male	6·4	5·4	14·2	12·4
	Female	6·6	6·2	—	9·3
Portuguese	...Male	16·6	16·4	15·4	23·8
	Female	25·0	24·8	16·7	21·3
Chinese ...	...Male	—	—	—	10·0
	Female	—	—	—	4·5
Europeans	...Male	—	—	—	9·4
	Female	—	—	—	7·7
All above	...Male	10·8	9·7	19·5	22·4
	Female	20·1	17·3	23·3	19·3

Column A gives the percentage found amongst the patients of Georgetown Hospital by Conyers and Daniels in 1896 ; column B gives the corresponding infection found by Wise in 1908 ; column C shows the percentage found by Rose in 1919-20 during a general survey of normal members of the population ; column D gives the percentage found in Georgetown by us

These figures show a considerable increase in the general filarial infection during the past quarter of a century, and as the rate amongst women has remained fairly constant, the increase is much more marked amongst the males. Modern methods of examination differ but slightly from those practised by the older observers, and could not account for such a striking variation.

Albert Town.—In order to get an accurate idea of the filarial rate in the heart of Georgetown, the Commission decided to make an intensive examination of the residents in a compact area. The most suitable area for this purpose was the municipal district of Albert Town because it was largely inhabited by typical working-class citizens, and it was situated in convenient proximity to the laboratory. In this district three blocks of residences were selected, and the Government Registrar kindly supplied a copy of the census returns made in April, 1921. The population of the three blocks given in the census register was 637. By regular domiciliary visits each night between 9 p.m. and 10 p.m. for about a fortnight the Commission, assisted by Drs. F. G. Rose and Ewing-Chow, examined altogether 515 individuals, or 81 per cent. of the population of the area. Table VI. gives the results of the blood examination in these cases. All infections were *F. bancrofti*.

TABLE VI.

ALBERT TOWN.

Races.	Males.			Females.		
	Number examined.	Number with Micro-filariæ.	Per-centage.	Number examined.	Number with Micro-filariæ.	Per-centage.
Blacks ...	128	45	35·2	210	58	27·5
Mixed	53	18	34·0	71	16	26·0
East Indians ...	6	4	—	7	2	—
Portuguese ...	15	6	—	20	7	—
Europeans ...	2	1	—	3	—	—
Total ...	204	74	36·3%	311	83	26·7%

Prisoners.—Through the kindness of the various authorities concerned, the Commission paid visits to H.M. Penal Settlement at Bartica and the prison in Georgetown. The prisoners in general were a healthy body of men and women drawn from all parts of the country, and the filarial

survey might be taken as representative of the incidence of infection amongst the lower classes of the Colony. Altogether 424 prisoners were examined, and 115 or 27 per cent. were infected with *F. bancrofti*. One Aboriginal Indian showed embryos of *F. perstans*.

Table VII. gives the percentage of infection for males and females amongst those who had resided in Georgetown and those drawn from country districts.

TABLE VII.

	Former Residents in Georgetown.			Former Residents in Country Districts.		
	Number examined.	Number with Micro-filariæ.	Per-centage.	Number examined.	Number with Micro-filariæ.	Per-centage.
Males	152	70	46·1	230	33	14·4
Females ...	28	10	35·7	14	3	21·4
Total ...	180	80	44·4%	244	36	14·8%

Table VIII. shows the infection rate according to racial distribution.

TABLE VIII.

Racial Distribution of Prisoners.

	Resident in Georgetown.			Resident in Country.		
	Number examined.	Number with Micro-filariæ.	Per-centage.	Number examined.	Number with Micro-filariæ.	Per-centage.
Blacks ...	143	68	47·5	134	23	17·2
Mixed	12	4	33·3	6	2	33·3
East Indians ...	17	4	23·5	99	12	12·1
Portuguese ...	3	1	—	2	—	—
Chinese ...	2	1	—	2	—	—
Europeans ...	3	2	—	—	—	—
Aboriginals ...	—	—	—	1	*F. perstans*	—

The figures in the above table point definitely to filariasis being largely an urban infection in British Guiana, and they again give premier position in the racial distribution to the Blacks. A survey of a number of cases in Berbice Lunatic Asylum gave similar results.

It is significant that in very few of the houses in Albert Town was there any mosquito netting used, and in practically all of them mosquitoes were plentiful. One of the sanitary inspectors kindly made a random collection of 1,660 mosquitoes from the houses visited by the Commission, and these were identified as follows :—

Culex fatigans, 1,429 ; *Ædes argenteus*, 187 ; *Mansonia titillans*, 3 ; *Ædes scapularis*, 41.

From the group of *Culex fatigans* 141 females were sectioned in celloidin, and 24·1 per cent. were found infected with filarial embryos.

New Amsterdam.—Next in importance to Georgetown, the town of New Amsterdam has a population of slightly over 8,000. A visit was paid one night to New Amsterdam Hospital, and the filarial infection was found to be 14 per cent. of the total blood examinations. The following table gives the racial distribution in the total of 100 cases examined :—

TABLE IX.

New Amsterdam.

	Males.			Females.		
	Number examined.	Number with Micro-filariæ.	Per-centage.	Number examined.	Number with Micro-filariæ.	Per-centage.
Blacks ...	38	6	—	29	7	—
Mixed	5	—	—	4	—	—
East Indians ...	18	1	—	6	—	—
Total ...	61	7	11·5%	39	7	18·2%

Chinese.—According to the census returns for 1921, the Chinese in British Guiana numbered 2,722, the majority of whom were native born. There was a tradition that none of the Chinese in the Colony had ever suffered from filariasis or elephantiasis, and the Commission was particularly anxious to ascertain whether there might be some racial immunity. For various reasons no previous survey of the filarial rate amongst the Chinese colonists had ever been undertaken, but through the great influence of Mr. David Ewing-Chow and the Chinese Association of Georgetown, Dr. C. U. Lee commenced a domiciliary visitation on extensive lines.

The survey embraced roughly 50 per cent. of the Chinese population in Georgetown, and showed at once that the theory of racial immunity was untenable. In Table X. the results of blood examination give a positive filarial infection by *F. bancrofti* of 7·4 per cent.

No frank case of elephantiasis was found amongst 442 individuals, and the incidence of lymphangitis, lymphadenitis, and other filarial manifestations was unusually low.

Dr. Lee discovered that the low incidence of filariasis amongst the Chinese could be accounted for by their careful attention to personal hygiene. Most of the women and a large proportion of the men retire to bed soon after dark, and practically all of them sleep under mosquito curtains. The infected cases were practically all found in the districts of Charlestown, Lacytown, and Werkenrust, neighbourhoods which are inhabited chiefly by the poorer classes.

TABLE X.

Chinese.

	Males.			Females.		
	Number examined.	Number with Micro-filariæ.	Per-centage.	Number examined.	Number with Micro-filariæ.	Per-centage.
Georgetown ...	209	21	10·0	222	10	4·5
Country districts	8	2	—	3	—	—
Totals ...	217	23	10·6%	225	10	4·4%

Age Incidence.

For a long time it was believed that the incubation period of filariasis extended into several years, as microfilariæ had not been found in the blood of very young children. The Commission made periodical examinations in the children's ward in Georgetown Public Hospital, and found positive infections under 5 years of age on several occasions. The youngest child with microfilariæ in the peripheral blood was 14 months old, and three infected children were under 2 years of age.

The education authorities kindly granted facilities for an examination of the children attending one of the large schools in Georgetown, and a con-

siderable proportion of the scholars were induced to return to school one evening accompanied by their parents. In this way over 200 children ranging from 4 to 16 years of age were examined for physical signs of filariasis, and blood-films were taken from 196.

Tables XI. and XII. give the analyses of these 196 cases in age groups according to symptoms and according to race.

TABLE XI.

CHRISTCHURCH SCHOOL.

	Number examined.	Number with Enlarged Glands.	Number with Elephantiasis.	Number with Microfilariæ.
4 to 10 years of age	106	68 = 64%	1 = 0·9%	12 = 11·3%
11 to 16 „ „	90	50 = 55%	4 = 4·4%	11 = 12·2%
Totals	196	118 = 60·2%	5 = 2·6%	23 = 11·7%

TABLE XII.

CHRISTCHURCH SCHOOL.

	Males.				Females.			
Age	4 to 10 yrs.		11 to 16 yrs.		4 to 10 yrs.		11 to 16 yrs.	
	No. examined.	No. with Microfilariæ.	No. examined.	No. with Microfilariæ.	No. examined.	No. with Microfilariæ.	No. examined.	No. with Microfilariæ.
Blacks ...	35	4	39	5	40	5	18	2
Mixed ...	10	1	11	–	10	1	13	3
East Indians	4	–	2	–	1	–	3	–
Portuguese	3	–	3	1	1	1	–	–
Europeans	2	–	1	–	–	–	–	–

The above tables show a high rate of infection even amongst children under 10 years of age, and as in all previous tables, the Blacks again occupy the premier position. A true estimate of the age period showing the highest filarial rate might perhaps be obtained from an analysis of the survey conducted in Albert Town. The collective results of this survey have already been given in Table VI. In Table XIII. the 515 inhabitants examined in this compact area are divided into age periods of 10

years, and only those are marked positive who had microfilariæ in the peripheral blood. It will be observed that the highest incidence is found in young people from 10 to 20 years of age, but even up till 50 years the percentage of infection remains fairly uniform.

TABLE XIII.
ALBERT TOWN.

Age-Periods	Up to 10 yrs.		11 to 20 yrs.		21 to 30 yrs.		31 to 40 yrs.	
	No. examined.	Positive for Microfilariæ.	No. examined.	Positive for Microfilariæ.	No. examined.	Positive for Microfilariæ.	No. examined.	Positive for Microfilariæ.
Males ...	61	16	49	18	25	8	19	8
Females ...	72	10	66	22	55	19	45	16
Total ...	133	26	115	40	80	27	64	24
Percentage Infection	—	19·5%	—	37·4%	—	33·7%	—	37·5%

Age-Periods	41 to 50 yrs.		51 to 60 yrs.		Over 60 yrs.			
	No. examined.	Positive for Microfilariæ.	No. examined.	Positive for Microfilariæ.	No. examined.	Positive for Microfilariæ.		
Males ...	18	8	15	7	17	9		
Females ...	37	11	19	3	17	2		
Total ...	55	19	34	10	34	11		
Percentage Infection	—	34·5%	—	29·4%	—	32·3%		

ELEPHANTIASIS.

Elephantiasis.—The racial distribution of elephantiasis is a question which has been raised in the four previous surveys conducted between 1883 and 1920. In the report of the Government Bacteriologist for British Guiana, 1920, Rose states that " the Portuguese, especially the Portuguese women, retain their priority of place." The Filariasis Clinique

conducted by the Commission in 1921, was attended by 352 cases of elephantiasis living in Georgetown, and the following table gives the number and percentage belonging to each of the different races, together with the percentage of these races living in the city at the last census.

TABLE XIV.

ELEPHANTIASIS IN GEORGETOWN.

	Number of cases of Elephantiasis who visited Clinic.	Percentage of all cases.	Percentage population of Georgetown. Census Records.
Blacks	205	58·2	49·9
Mixed	73	20·8	24·7
East Indians	26	7·4	10·8
Portuguese	39	11·0	9·4
Chinese	—	—	1·4
Europeans	9	2·6	3·7
Aboriginal Indians ...	—	—	0·1
Total	352	100·0	100·0

It is clear, therefore, that with the above criteria the priority of place seems now to rest with the Blacks.

Journal of Helminthology, 1923. *Vol.* I., *pp.* 227-236.

A Description of Two Cercariæ found in *Limnæa peregra* in Scotland.

By A. J. Hesse, B.Sc., Ph.D.

Introduction.

During the month of July, 1921, I had the opportunity of working with Dr. Annandale on the molluscs of Loch Lubnaig and Loch Vennachar in Perthshire, Scotland; and I was able to study carefully the two cercariæ infecting *Limnæa peregra*, Müll. The material was examined in the living condition. Some of it was fixed in sublimate acetic and preserved in alcohol for subsequent study in sections.

Every large *Limnæa peregra* examined was heavily infected with sporocysts of either of the two species, but it was rare to find both together. The Furcocercous cercaria was the more common, and was found in at least eight out of every ten *Limnæas*. A heavily infected individual may be recognised by the dull white appearance of its shell. The colour is due not to the shell, but to the underlying infected liver. The two kinds of infection may be distinguished through the shell.

In the xiphidiocercarial sporocysts are white or yellowish and plump in appearance; in the Furcocercous form they are yellowish, but thread-like and thin. Infected *Limnæas* are very sluggish in their movements, whereas the smaller and uninfected *Limnæas* are active.

The discharge of Furcocercous cercariæ reached its maximum at the end of July. Molluscs opened in the middle of August had empty sporocysts, containing comparatively few undeveloped cercariæ. The Xiphidiocercariæ were liberated in swarms only during certain very warm days in July. The number set free declined at the end of August.

The work has been done in the Department of Zoology of the University of Edinburgh. My thanks are due to Professor J. H. Ashworth and to Dr. N. Annandale.

The Furcocercous cercaria.

The *sporocysts* are long worm-like structures, and in all the Limnæas examined, they were so numerous and involved that it was difficult to separate them or to obtain an undamaged one. They arise in or near

the ovo-testis (hermaphrodite gland), and as development proceeds they extend into the liver and finally destroy the entire organ.

The individual sporocyst presents to the naked eye the appearance of a piece of thin cotton. It may reach a length of 1 cm. with a maximum thickness of .15 mm. The entire sporocyst is active, its pointed anterior end especially so as it continually oscillates from side to side. The sporocyst is usually uniform in diameter, but in some cases has become constricted at certain points and resembles a string of sausages. The constrictions are probably due either to points of maximum resistance of the liver tissue, or to incipient transverse division of the sporocyst.

The sporocyst is white, sometimes slightly tinged with yellow or brown; the extreme anterior end is yellow. About .1 mm. from the anterior end is a birth-pore. About .08 mm. from the anterior end is a ridge, which is not constant.

Externally the sporocyst is covered with flat epithelial cells, the spaces between which are filled with a granular material.

Internal to the epithelial layer is a muscular layer, below which is a layer of cells, from which the cercariæ arise. Anterior to the birth pore the sporocyst is completely filled with a mass of cells, and this region marks the locality of primary cell-proliferation. Behind the birth pore the sporocyst exhibits a cavity bounded by a thin cuticular membrane. The cercariæ arise from germinal elements, and as the cells increase in number, each group or cluster becomes constricted from the internal lining to which, however, it remains attached by a thin homogeneous non-cellular strand. In some instances similar strands connect adjacent embryos. The wall of the sporocyst exhibits peristaltic movements and the contained cercariæ of various ages—the younger still connected to the wall—are kept in movement. Every movement brings a mature carcaria nearer to the birth pore. Ordinarily they are passed out regularly at the birth pore, but rupture of the wall may occur when the sporocyst is overcrowded with mature cercariæ.

The CERCARIA is translucent, with a slender body and a stout tail with two lanceolate forks. The oral region is very contractile, and the walls of the buccal cavity are protrusible.

The body is concave ventrally and convex dorsally. The tail is inserted terminally in a small pocket the margins of which are slightly overhung by the posterior margin of the body.

The anterior end of the body is covered with transverse rows of minute recurved spines. The extreme anterior rows are close together and enter the buccal cavity. Posteriorly the rows become further apart and soon disappear on the dorsal surface, but scattered spines are present on the ventral surface as far back as the ventral sucker. The remainder of the body is smooth, and bears no processes except two backwardly directed bristles laterally on each side, and .01 mm. from the posterior end.

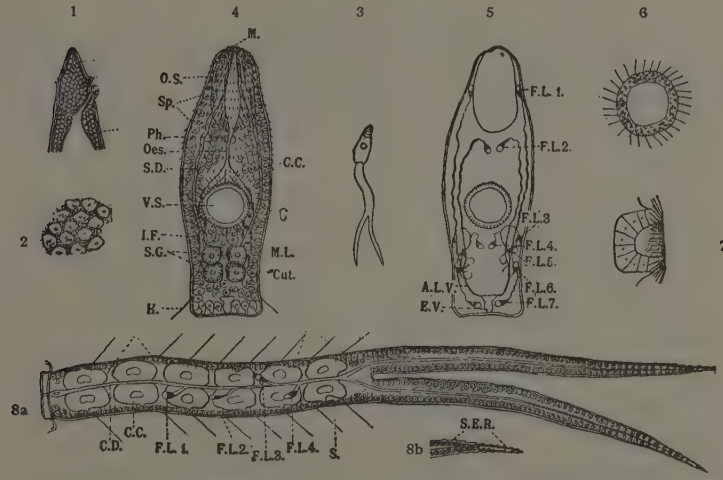


Fig. 1. Sporocyst, showing ridge and birthpore.
Fig. 2. Sporocyst, epithelial layer.
Fig. 3. Furcocercous Cercaria.
Fig. 4. Cercaria body showing mouth (M). O.S. oral sucker. Pharynx (Ph). Oesophagus (Oes) Salivary Gland (S.G.) Hairs (H).
Fig. 5. Cercaria body showing position of Flame cells (F.L.) ducts and excretory vesicle.
Figs. 6, 7. Ventral sucker showing three rows of spines seen vertically (6), laterally (7).
Fig. 8a. Tail showing the hairs and large caudal glands (C.C.). Flame cells (F.L.).
Fig. 8b. Serrations on tip of fork of tail (S.E.R.).

There are two suckers, a powerful oral sucker surrounding the mouth and a ventral sucker bearing three rows of spines. The first row, situated on the rim, consists of long spines, each with a stouter basal part, embedded in the muscles, and a needle-like distal part about .008 mm. long, fixed at an angle with the basal part. The spines are movable, and their orientation depends upon the state of retraction or extrusion of the sucker. The spines of the second row are blunt and knob-like, and alternate more or less with the basal elements of the first row. Deeper

down in the cavity of the sucker is a third series, but these are mere tubercles.

The tail is thick and powerful, and is transversely striated. It bears stiff hairs, reaching a length of .013-.02mm., but these are few and far apart. The two forks of the tail are flattened, and are as long as, or slightly longer than the basal part. No hairs could be seen on the forks, but the dorsal and ventral edges, especially posteriorly, have a serrated appearance.

Internal Anatomy.

Alimentary Tract.—The tubular œsophagus bifurcates immediately anterior to the ventral sucker. Each fork can be seen as a string of about six clear, transparent cells situated in the dorsal region of the cercaria. A little posterior to the oral sucker is a cluster of cells opening into the œsophagus. (Fig. 4.) The salivary glands are four large coarsely granular cells, two on each side, having a diameter of about .01 mm. situated ventrally and behind the ventral sucker. They are sometimes placed obliquely, one behind the other. The salivary ducts are lateras and run anteriorly, passing through the walls of the oral sucker to their external openings, one on each side of the mouth. During their course through the wall of the oral sucker they become dilated.

Excretory System.—There are 14 flame cells—seven pairs. Their disposition in the body is shown in Fig. 5.

The excretory vesicle is T shaped. It has a length of about .01 mm. and a breadth of about .007 mm. The excretory system in the tail is highly developed. There are four flame cells, each of them opening by a short duct into the main caudal vessel. One of these flame cells is situated anterior to each of the last four pairs of large caudal cells.

There are six large caudal cells on each side of the main vessel. They are not always opposite to each other, and sometimes an extra one occurs on one side, so that the total number is 13. These cells are large, about .025 mm. long and .012 mm. broad. They contain large hyaline nuclei, and the cytoplasm is clear and fluid, but collapse when fixed. Some of these cells are connected to cells in the wall of the tail by a thin strand. That these cells have an excretory function is suggested, as their inner walls bound the caudal canal. The main caudal vessel is median in position. It receives a duct from each fork, and opens into the posterior arm of the excretory vesicle.

Glands and Cells.—The region between the alimentary canal and the body wall is filled with parenchymatous tissue. The gonads have not yet been differentiated.

The wall of the tail is constituted of a layer of small cells. The tail is very muscular, longitudinal and circular fibres being visible under the cuticle.

Measurements of Living Cercariæ.

(The figures in brackets which follow are the corresponding measurements from specimens fixed in sublimate acetic and examined in alcohol.)

Length of body	.14–.16 mm. (.12–.15 mm.)
Breadth of body anteriorly	.025 mm. (.02 mm.)
Breadth of body posteriorly	.04 mm. (.025–.04 mm.)
Breadth of body in middle region (maximum) ...	.05 mm. (.04–.05 mm.)
Thickness of body in the region of the ventral sucker about	.043 mm. (.035 mm.)
Thickness of body in posterior region	.023 mm. (.023 mm.)
Length of tail	.19–.2 mm. (.16 mm.–.19 mm.)
Length of fork	.2–.22 mm. (.17 mm.–.2 mm.)
Breadth of tail	.03–.035 mm. (.03 mm.)
Breadth of fork at base	.015–.019 mm. (.012–.014 mm.)
Length of ovate oral sucker about	.05 mm. (.04–.05 mm.)
Maximum breadth of oral sucker about	.025 mm. (.025 mm.)
Diameter of ventral sucker (uncontracted) ...	.03 mm. (.03 mm.)
Diameter of ventral sucker (contracted)	.018–.024 mm. (.02 mm.)

The anterior margin of the ventral sucker is about .084–.09 mm. (.06–.08mm.) from the anterior end.

Motions of the Cercariæ in Water.

These cercariæ do not emerge from the Limnæa in " puffs " or swarms, but pass out one by one, at the rate of about four or five per minute. They are positively phototropic. They swim obliquely upwards, tail directed forwards and body downwards, and come to rest on the illuminated side of a tube, with the body turned symmetrically to the light. If the tube is now slowly turned round the cercariæ become active again, and migrate towards the light.

The large caudal cells of the tail seem to give buoyancy to the cercaria.

The cercariæ which have lost their tails creep leech-like, moving their mobile and contractile anterior ends from side to side. The cercaria was not observed to encyst, and probably has to gain entrance into the final host by penetration. The spines on the ventral sucker, together with the spiny anterior extremity, probably help the animal to penetrate the epidermis of the host. The secretion of the four salivary glands probably aids in the act of penetration. The liberated cercariæ were observed to live in water for 48 to 72 hours. The definitive host is unknown.

The Xiphidiocercaria.

The Sporocysts containing the cercaria are situated in, and sometimes form knob-like projections on the surface of the liver. They are blunt, thick and short, and in the living condition are opaque and white. Empty sporocysts have a definite tinge of yellow. They are not straight, but bent upon themselves, and show no movement. They may reach a length of 1.5 mm. to 3 mm. and a breadth of .2 mm. to .5 mm.

The external layer is cellular and granular. Traces of a black pigment are found on the surface. Internal to the epithelial layer is a layer of cells from which the embryos arise. It is difficult to localise a definite centre of origin of the embryos as these are scattered throughout the sporocyst cavity. Early embryos are attached to the wall of the sporocyst by thin strands.

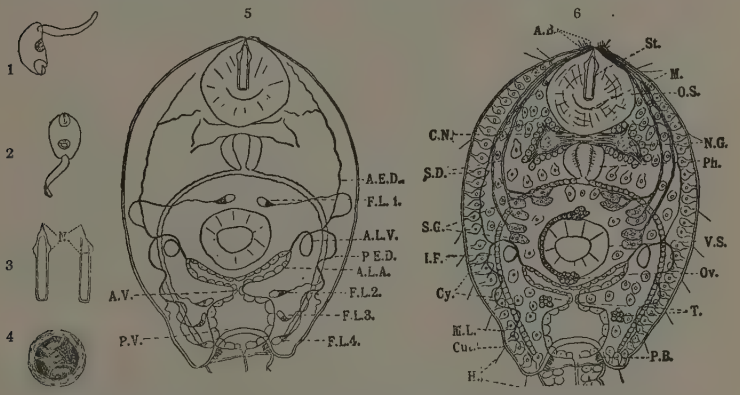
The cercaria, especially the anterior extremity, is contractile and is capable of great modification, assuming either a more elongated or a more globular form. The normal form, while in suspension in the water, is oval with the maximum breadth anterior to the ventral sucker. The anterior third is more or less transparent, but the posterior part is opaque. When examined alive in water the body is convex dorsally and concave ventrally, and the lateral margins of the body in lateral aspect tend to hide the ventral sucker. The anterior and posterior extremities are both directed downwards, the oral sucker and caudal pocket being subterminal. The posterior margin of the body projects rim-like over the base of the tail. The lateral extensions of the posterior margin are a little longer than the dorsal rim. In the normal condition the tail gives the impression of being inserted almost at right angles to the body. The caudal pocket has a cuticular lining, the surface of which is slightly thicker opposite the lateral extensions of the body. This thickened part is beset with minute bristles directed towards the base of the tail.

The cuticle of the body is covered with rows of minute bosses or tubercles, which are better developed anteriorly and also posteriorly in the region of the caudal pocket. They are arranged in intersecting rows, and form a " diamond pattern." The cuticle of the tail is smooth, but transversely striated. Besides the tubercles the body is covered with fine hairs or bristles, .01 to .02 mm. in length, scattered over the posterior three-fourths at intervals of .02 to .04 mm. These hairs are easily broken

off. In most of the specimens there were nine transverse rows. The first two rows are close together and their position is fairly characteristic of this cercaria. Six characteristic bristles project forward on each side of the stylet. One of these—the fifth from the stylet—is much longer than the others. These anterior bristles have been found in all the specimens of this Xiphidiocercaria examined.

The tail possesses no hairs or bristles, but the cuticle is often seen to be raised into membranous extensions, which seem to be due to the effect of the water, for freshly liberated cercariæ do not possess them.

The oral sucker is larger than the ventral sucker, and in its dorsum



Figs. 1, 2. Outlines of Xiphidiocercaria.
Fig. 4. Encysted cercariæ.
Fig. 3. Stylet: dorsal and lateral views.
Fig. 5. Body showing excretory system and Flame cells.
Fig. 6. Body showing glands, etc.

A.L.A. Antero-lateral arm of vesicle.
A.V. Anterior part of excretory vesicle.
A.B. Anterior bristles.
C.N. Nerve sheath cell.
Cu. Cuticular cell.
Cy. Cystogenous cell.
H. Hairs.
M.L. Muscle layer.
O.S. Oral sucker.
Ov. Ovary.
P.B. Pocket bristles.
P.V. Posterior part of excretory vesicle.
S.D. Salivary duct.
S.G. Salivary gland.
St. Stylet.
T. Testes.
V.S. Ventral sucker.

there is a stylet, cylindrical proximally, but with a nib-like distal part. The average length of the stylet is .034 to .037 mm., the diameter at the base is .005–.006 mm., and at the base of the "nib" is .009–.01 mm. At the base of the "nib" on the ventral surface is a band-like reinforcement, which extends from the ventral on to the lateral surface, and is about .003 mm. in thickness. The length of the "nib," measuring from the distal edge of the rim, is about .01 mm. The stylet is subject to slight variations in form in different individuals, *e.g.*, the

reinforcement may be present only on one of the lateral surfaces. The main body of the stylet is hollow, but the " nib " is solid. The stylet is situated obliquely, and dorsal to the mouth. The reinforcement does not extend on to its dorsal surface, so that in profile the dorsal surface of the stylet is a straight line.

Internal Anatomy.

Alimentary Tract: (Fig. 6).—There is a small pharynx with muscular walls. An œsophagus is absent, the two forks of the intestine seem to arise from the pharynx, and may be traced each as a single curved row of cells to the posterior lateral region of the body. The interval between the bifurcation and the ventral sucker is comparatively large.

The *excretory system* (Fig. 5) possesses eight flame cells, two of which are pre-acetabular and six post-acetabular.

The anterior part of the body is drained by two ducts, one on each side of the body, which run posteriorly. Each duct arises in the lateral region of the oral sucker and receives a small duct from the region of the pharynx, and another from a flame cell close to the anterior margin of the ventral sucker. The posterior region is drained by two ducts, one on each side of the body, which run anteriorly. Each of these ducts receives tributaries from three flame cells, and a duct from the postero-lateral region of the body.

The anterior and posterior main ducts on each side of the body unite to form a coiled lateral vessel which opens into an arm of the excretory reservoir. The posterior end of the vesicle receives a single duct, which traverses the tail. No flame cells were visible in the tail.

The excretory reservoir is Y-shaped, having two non-contractile antero-lateral arms, each about .03–.04 mm. long, and a median posteriorly directed contractile vesicle about .04 mm. wide.

Genital System.—The gonads are represented as masses of germ cells, and are as yet feebly differentiated. The testes occur as two masses at the level of the excretory vesicle, near the ventral surface. They are not exactly connubial, for the left one is situated a little in front of the anterior margin of the vesicle. The ovary is median and situated near the dorsal surface above the posterior edge of the ventral sucker. From it passes forwards a semicircular string of cells situated dorsally and to the left margin of the ventral sucker. At the level of the anterior margin

of the sucker the string of cells extends ventrally in an oblique direction towards the pre-acetabular field. There is no doubt that these structures, which stain deeply, are the " anlagen " of the oviduct and uterus.

Glands and Cells.—On each side of the animal and lateral to the ventral sucker there are six granular cells divided into two groups. The posterior group on each side consists of two transversely placed cells, with a diameter of about .01–.013 mm., situated close together and lateral to the ventral sucker. From each pair there extends anteriorly a small duct which is sinuous in the contracted condition of the cercaria. Anterior to these, and also situated transversely, is a cluster of four glands on each side. Two of each group extend into the median field anterior to the ventral sucker. From these anterior groups ducts pass anteriorly, extend laterally round the oral sucker, and open by pores into the slight invagination, on each side of the stylet.

The space between the alimentary tract and the body wall is filled with parenchyma and other cellular elements. Some of the latter, situated close under the cuticle, are small and correspond to dermal glands. Certain others, flask-shaped and slightly granular, with fairly large nuclei, correspond in character with those designated as cystogenous glands. They are most abundant lateral and posterior to the ventral sucker. Some of the parenchyma cells of the body and the tail are much distended, and in most cases they collapse on fixation.

Nervous System.—Posterior to the oral sucker and dorsal to the short pre-pharynx is a commissure, resting like a saddle on the pre-pharynx, which connects the two laterally situated ganglionic masses.

Measurements of Living Cercariæ.

(The figures in brackets which follow are the corresponding measurements from specimens fixed in sublimate acetic and examined in alcohol.)

Length of body about	.14–.25 mm. (.12–.25 mm.)
Breadth of body anteriorly	.08 mm.
Breadth of body (maximum)	.1–.17 mm. (.12–.135 mm.)
Thickness of body anterior to the ventral sucker ...	.053 mm. (.09 mm.)
Thickness of body posterior to the ventral sucker ...	.035 mm.
Length of tail, depending on its state of contraction or extension	.11–.35 mm. (.15–.2 mm.)
Breadth of tail at base	.035 mm. (.03–.05 mm.)
Diameter of the oral sucker	.05–.06 mm. (.04–.05 mm.)
Diameter of the pharynx	.023 mm. (.023 mm.)
Diameter of the ventral sucker	.04 mm. (.04 mm.)
The ventral sucker may protrude	.02 mm.

The anterior margin of the ventral sucker is about .134 mm. (.1 mm.) distant from the anterior margin of the body.

General Observations.

The cercariæ escape from the mollusc in great numbers and slowly swim away, rising towards the surface film.

The cercariæ are exceedingly active, but their progress is slow, and they remain witin a limited area for a long time.

This cercaria encysts on the shell of *Limnæa peregra*, preferably on that of a young Limnæa. The body becomes hemispherical, concave ventrally and convex dorsally. Drops of fluid can be seen exuding through the cuticle, and a mucous layer is formed. The encysting cercaria is not quiescent, but continually moves its anterior extremity through an angle of about 180°. Frequently the whole body exhibits undulatory movements which appear to be essential for the production of a uniform cyst. The stylet glands probably co-operate in the formation of the cyst wall. Drops of a secretion can frequently be seen exuding even in unencysted forms. The cyst wall consists of concentric layers. (Fig. 5.) The whole cyst is opaque and dark in appearance, owing to the dark brown cercaria inside. The diameter of the cyst is about .22–.23 mm., and its wall is .03–.04 mm. thick.

Non-encysted cercariæ may survive for 24 hours in an aquarium, but unless a *Limnæa* is reached within that time, they die and decompose. A few were observed to encyst on the walls of the glass dish. All the cercariæ do not encyst even when *Limnæas* are present. The percentage of encysting individuals is small in comparison with the large numbers liberated. The finding of a *Limnæa* seems to depend upon chance. A special vitality or activity is, however, shown when the cercariæ reach the *Limnæa*. When several *Limnæas* are present, relatively more cysts are formed on the shells of the smaller examples. The definitive host no doubt is one that preys upon *Limnæa*.

The cercariæ were studied in July and August. The warm summer days of July seemed to favour their liberation. The cercariæ are liberated in quiet bodies of water, such as little bays and pools.

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CORRIGENDA FOR VOL. I.

Page 89, Legend to Fig. 13, add "B and C after Molin."

Page 126, line 16 from bottom, for ".01" read ".1."

Page 134, line 11 from top, for "Fig. 1" read "Fig. 2."

Page 144, line 3 from top, for "Endoparasitic in stem tissue of" read "Ectoparasitic on."

Page 147, line 9 from top, delete the words "enters the stem tissues and."

Page 168, line 2 from bottom, for ".66" read ".46."